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TL Cement

TL CEMENT, LDA

VOLUME II

Baucau Cement Project

Environmental Impact Statement - Cement Plant, Jetty, Conveyor Belt and Associated Infrastructure

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Venture Hotel - Rua Filomena De Camara
Bidau Lecidere PO Box 7 Dili
Timor Leste
Telephone: +670 331 3238 & 331 3238
Facsimile: +670 772 8144
www.worleyparsons.com
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TL CEMENT, LDA
BAUCAU CEMENT PROJECT
ENVIRONMENTAL IMPACT STATEMENT - CEMENT PLANT, JETTY, CONVEYOR BELT AND ASSOCIATED INFRASTRUCTURE

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PROJECT 301012-02135 - BAUCAU CEMENT PROJECT

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Appendices

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Appendix 1 Air Quality Impact Assessment Study Report

TL CEMENT Lda.

Air Quality Impact Assessment Study of Clinker Cement Project

Baucau - TimorLeste

Final Report

No : 15.3380 - FR – 001

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Prepared by:

PT. **BITA** BINA SEMESTA

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EXECUTIVE SUMMARY

TL Cement LDA, a privately-owned company, proposes to construct a Greenfield cement manufacturing project in Baucau Municipality, Timor-Leste. The project will produce approximately 1.65 million tons per annum (Mtpa) of Portland cement clinker. The air quality impact assessment study has been conducted to predict the impact to the air quality during the construction and operation phase of this cement manufacturing project, as well as setting up the mitigation measures for negative impacts.

The concentration of primary air pollutant in the form of PM_{10}, $PM_{2.5}$, carbon monoxide (CO), nitrogen dioxide (NO_2), sulphur dioxide (SO_2), hydrocarbon (HC) and secondary air pollutant in the form of ozone, were measured in six representative sensitive receptors for the baseline study, which are located in settlement area (Bahu, Triloca, Aldeia Osso-ua, Walaicama and Bucoli,) and school area (Aldeia Parlementu).The baseline data shows that background concentrations of all measured parameters were below the limit according to international air quality guidelines. Baucau meteorological data were collected from Baucau Meteorological Station, located at 08° 28'12''S and 126° 27'0'' E, 451 m above the sea level, and about 5 km away from the location of future cement plant. The relative humidity was recorded between 28%-100%, with daily temperature between 18^{o}C to 32^{o}C. In general, as the temperature increases the relative humidity usually decreases or vice versa. The wet season lasts from December to June while the dry season lasts from July to November. During the wet season, the highest rainfall was recorded in December (203 mm), while for the dry season the highest rainfall was in November (20 mm). There were many days, especially from July to October where there were no rain at all (0 mm/day). Those days might have the highest level of air pollution, since there would not be pollutant washout by rain through the wet deposition mechanism.

Since 87.5% of hourly meteorological data for one year from Baucau station were missing, complete hourly meteorological data for one year were collected from *weblakes* to conduct the air quality modelling. Metrological data from *weblakes* are generated using MM5, a prognostic meteorology model developed by Pennsylvania State University and the U.S. National Centre for Atmospheric Research (NCAR) which is capable of generating high resolution of hourly meteorological data.This complete set hourly meteorological data is very important since it will strongly influence the accuracy of predicted future ambient concentration during construction and operation phase of the project.According to annual behaviour of prevailing winds, the receptors that undergo the most frequent exposure to the air pollutant will be those who live in North West of Baucau since prevailing winds mostly blow from South East direction. These receptors may also have the highest probability to expose to the highest level of air pollutant concentration, since in the driest month (July - September), the prevailing winds also blow to this direction. Receptors that live in other directions may also expose to the emitted air pollutant, but in a lower exposure frequency.

Impact assessment of cement TL activities was carried out quantitatively by using modelling tools, both during construction and operation phase. The impact assessment divided into two major parts, i.e.; the emission inventory and prediction of future ambient air quality. Emission rates from inventory calculation become the input for prediction of future ambient air quality combine with other supporting data such as meteorological data and topographical data. ISC AERMOD View, a steady state plume model was used to predict the ambient concentration surrounding the project area during construction and operation phase. This model was chosen over other available models since the prediction was carried out for a short range transport (less than 50 km), only limited meteorological data available in project area, and previous study comparing AERMOD with other model such as RAMS showed similar results for short term average concentration when using identical input data. Steady state models generally do not underestimate the estimated concentration; therefore provide a sound basis for regulatory compliance model. Results of prediction are presented in the form of isopleth of each concentration over the receptor area.

During the construction phase, predicted ambient concentration for all averaging time and all air pollutant parameters were below the ambient standard. While during operation phase, predicted ambient concentration for PM_{10}-$PM_{2.5}$ (24 hour and annual averaging time), CO-SO_2 (1 hour, 24 hour, and annual averaging time) and NO_2 (annual averaging time) were also below the ambient standard. Only 1 hour NO_2 concentrations (highest concentration: 222 µg/Nm^3) were predicted to be slightly above the standard (200 µg/Nm^3 according to WHO standard)). Total number of 1 hour NO_2 calculated data were 3,924,480 data (derived from 448 receptors x 8760 hour in a year), and total number of exceedance (data above ambient standard) are 25 data only, therefore the exceedance percentage was only 0.0006%. The location which would undergo probable exceedance of 1 hour NO_2 concentration was located inside the limestone mining area, and would not reach the closest sensitive receptor, i.e. the settlement area in Aldea Osso-ua (the 1 hour NO_2 concentration in this location was predicted to be 100 to 150 µg/Nm^3)

Modelling results also showed that during the construction phase, the highest concentration might occur less than 500 m away from the construction activities. During the operation phase, the highest concentrations generally occurred farther at 1 up to 3 km away from the main sources (such as stacks). In general, pollutants tend to disperse to the North West direction from the sources, in the opposite direction from where the prevailing winds blow (prevailing winds blow mostly from south east direction). Moreover, the area located in the south east direction from the sources (plant and mining area) has a higher level, which is capable of preventing pollutant dispersion by topographic barrier. The dispersed pollutants are predicted to be able to reach the sensitive areas, but the concentration level reaching these areas are all below the standard for each averaging time. Sensitive receptors which may experience higher dispersed concentration than other receptors are located around the jetty plant area (scattered small cluster of fisherman village), settlement area in Aldeia Osso-ua, and settlement area in Wailacama north east of clay quarry.

Although the impact assessment using modelling tool has shown that the future ambient concentration generally below the ambient standard, mitigation during construction and operation phase must be implemented to keep the concentration of air pollutants in the ambient air in allowable level. Parameters which will be monitored are PM_{10}, $PM_{2.5}$, CO, NO_2, and SO_2 (representing the primary air pollutant) and ozone (representing the secondary air pollutant). Monitoring will be conducted in sensitive receptors such as settlement area in Bahu (east-south east of cement plant), School area in Aldeia Parlemento (east of cement plant and north east of limestone mine), settlement area in Aldeia Osso-ua (close to cement plant area), and settlement area in Wailacama (north east of clay quarry). Mitigation for emission sources will also be conducted to keep the emission concentrations not to exceed the limit value. Particulates (from kiln, thermal power plant, cooler ESP stack, cement mill bag house, and coal mill bag house) will be maintained not to exceed 30 mg/Nm^3), gases (from kiln only) not to exceed 200mg/Nm^{3}for SO_2, 800 mg/Nm^{3}for $NO_2$and 500 mg/Nm^{3}for CO. A mitigation monitoring and reporting program will also be developed and reported to the local environmental agency for a certain period of time (at least every six month) to ensure the air quality parameters do not violate the standard.

1. INTRODUCTION

1.1. Brief Project Description

TL Cement LDA, a privately-owned company, proposes to construct a Greenfield cement manufacturing project in Baucau Municipality, Timor-Leste. The project will produce approximately 1.65 million tons per annum (Mtpa) of Portland cement clinker.

Clinker refers to small lumps (3.0-25.0mm diameter), produced by heating limestone and other materials such as clay and sand in a cement kiln. Clinker, if stored in dry conditions, can be kept for several months without appreciable loss of quality. Because of this, it can easily be handled by ordinary mineral handling equipment, clinker is traded internationally in large quantities. Clinker is then ground to a fine powder, along with gypsum and other substances to produce useable cement.

The proposed project will provide cement for both domestic use and international sale. A feasibility study is currently being undertaken to demonstrate the commercial viability of the project.

The proposed project represents a significant investment of approximately $350 million and the largest industrial project undertaken in Timor-Leste to date. It is anticipated to create 1000 jobs at the peak of the construction. It will then continue to have 700 permanent employees during operation. The project aims to develop local capacity and will develop a training center.

The spin off benefit would be indirect employment to local community members, through the multiplier effect due to downstream socio-economic benefits and consequent improvement in the living conditions of local population in the project area.

A. <u>Cement Clinker Plant</u>

The plant includes clinkerisation and cement grinding facilities with a rated capacity of 5,000 tons per day (tpd) of clinker and 100 tons per hour (tph) of cement. The plant also includes a waste heat recovery (WHR) power plant.

Up to 60% of 0.53 Mtpa of cement will be sold in the local markets and balance 40% will be shipped to Australia in 8,000 Deadweight-Ton (DWT) ships either in bulk or in. Balance clinker of 1.15 Mtpa will be shipped in vessels of 40,000 DWT ships to Australia.

The project involves developing a green field plant including, but not limited, to the engineering, design, manufacturing and supply of new equipment for cement plant, a waste heat recovery based power plant, a captive thermal power plant of approx. 30 MW and Port (Double wharf jetties) about 1.5-2 Km from the plant site.

B. <u>Thermal Power Plant bottom and fly ash utilization</u>

The waste from the thermal power plant will be fly ash and bottom ash. The total ash will be utilised in the cement grinding for producing PPC based on the coal data and ash in the coal the fly/bottom ash generation will be approximately 50 t/day i.e. approx 16500 t/annum. This will produce around 66000 t/a of PPC based on 25% ash in PPC. All ash from the thermal power plant will be transported pneumatically to the cement grinding section.

C. <u>Mines and Raw Materials</u>

The raw and fuel material requirements for the proposed plant are to be met from different sources as given in Table below.

Table 1.1 Raw Materials

No.	Material	Source	Source Locality	Remarks
1.	Limestone	Local	SucoTirilolo, Bahu, Caibanda, Triloca, Bucoli, Wailili and Fatumaca in administrative post Baucau, Vemasse and Venilele , Baucau Municipality	Primary raw material. Transported from mine site to crusher by trucks.
2.	Clay	Local	Suco Wailacama, Baucau administrative post in Baucau municipality	A corrective material. Transported from quarry to plant by road.
3.	Iron Ore	Import	Australia	A corrective material. Transported to Timor-Leste by ship or barge, offloaded at jetty, and transported to plant by belt and Pipe conveyor.
4.	Gypsum	Import	Australia or other	A corrective material. Transported to Timor-Leste by ship or barge, offloaded at jetty, and transported to plant by belt and pipe conveyor.
5.	Coal	Import	Australia/ Indonesia	Fuel source and corrective material. Transported to Timor-Leste by ship or barge, offloaded at jetty, and transported to plant by belt and Pipe conveyor.

D. Limestone Deposit

The limestone deposit is accessible from Baucau by a tar road. The mine is located about 1 km from the main road and Bucoli village. The mining area is located around 0.5 km from the coastline where a jetty is proposed to be constructed. The limestone concession area (I-1) which shall meet the initial limestone requirement of the plant covers an area of 576 ha. The deposit area is generally undulating and hilly. As observation result, the limestone bearing area is covered by thick or scattered trees, thorny bushes and tall grass.

E. Clay Deposit

Clay is found to occur close to the plant site in Suco Wailacama in Baucau administrative post, less than 10 km west of the plant site. Clay shall be used as corrective to compensate for silica and alumina deficiency in the raw mix. Clay is proposed to be transported to the plant site by trucks.

F. Jetty

A dedicated jetty is proposed at a distance of 2 km from the plant site. Inbound material, (e.g., coal, gypsum, iron ore) and outbound clinker shall be transported between the plant and the jetty by a 0.5 km long conveyor belt + 1.5 km Pipe Conveyor (fully enclosed). The maximum load during unloading is estimated as 1000 tons per hour and during loading is estimated as 1000 tons per hour.

G. Utilities

a. Power

Power will be supplied by captive thermal power plant of approximately 30 mega-watts (MW) capacity and Waste Heat Recovery power plant.

Power for initial phase of plant operation when cement grinding is commissioned will be from grid power. Tapping from the nearby grid line of 20 KV will be tapped and step down to 11 KV at the plant substation. Generator sets will be utilized for construction power.

Emergency power requirement for initial commissioning of cement grinding is not required. For full plant 1.5 MW generator will be required. Thermal power plant shall include black start power requirement separately.

b. Water Supply

The water requirement for the cement project shall be met from groundwater by drilling bore wells. A makeup water supply of approximately 3,150 m^3/day is required for operations including requirement of mines, colony and green belt which may be possible to obtain this from one or two boreholes.

An underground aquifer is reported to occur below the mining blocks. As there is no industry in the area, the exploitation of water resources during the operation is not expected to adversely affect the water availability in the area for other competing users.

A detailed hydro geological study is proposed to be carried out to assess the availability of groundwater in the area. Water shall be required for:

- Process Water Circuit
- Cooling water (required for machine cooling)
- Make-up water shall be provided while re-circulating water shall be in a close loop
- Water required for township
- Water for on-site facilities
- Construction and operations (dust suppression)

c. Waste Water

The cement plant is being designed as a Zero Discharge facility and there shall be no discharge of waste water outside the plant premises. All the process waste water shall be treated in Water Treatment Plant and reused for plantation purposes. The waste water generated from domestic activities shall also be treated and reused for dust suppression, green belt development to the extent possible.

d. Solid Waste

Domestic solid waste generated from plant and jetty area shall be segregated and will be sent to waste disposal site as allocated by the local administrative authorities.

1.2. Location Study

The proposed cement plant and marine jetty are located in Suco Tirilolo, Aldeia Ossoa, in the Baucau administrative post of Baucau municipality, Timor-Leste. The location is about 120 km east of Dili and approximately 16 km west of Baucau.

The Proponent has been granted a Prospecting License for limestone over three blocks, including, Block I-1 (Bucoli North Area-1), covering areas of 576 ha. The prospecting blocks are spread over Sucos Tirilolo, Bahu, Caibada, Triloka, Bucoli, and Wailili in administrative posts of Baucau, Vemasse and Venilele in Baucau municipality.

Sources of clay are located at Suco Wailacama within 10 km from proposed plant site. Corrective iron ore and additive gypsum are proposed to be procured from Australia. Coal will be used as a fuel for the kiln and power supply at the cement plant and is proposed to be procured from either Indonesia or Australia. The location of plant, mines (Block I-1) and jetty are shown in figure below.

Source : *https://commons.wikimedia.org/wiki/File:Sucos_Baucau.png*
https://www.mof.gov.tl/about-the-ministry/statistics-indicators/sensus-fo-fila-fali/download-suco-reports/baucau-suco-reports/

Figure 1.1 Location of TL Cement Development Project

1.3. Scope Of Work

According to scope of works from WorleyParsons, the air quality impact assessment study will assess the following task :

- Preparation of baseline status of the ambient air quality through a scientifically designed ambient air quality monitoring network based on the following considerations: a) metrological conditions on synoptic scan; b) topography of the study area; c) representative of likely impacted area within the study area; d) location of residential areas representing different activities.
- Preparation extensive air quality modelling to predict the likelihood of impacts on sensitive receptors, and
- Identifying avoidance measures or design mitigation measures.

2. METHODOLOGY

The methodology section describes the detail methodology used in data collection, calculation, and assessment which includes:

- Description of established method for measurement of air quality background concentration[1] and collection of meteorological data. Collected data shall be used to set up the air quality baseline surrounding the project area.
- Description of methodology for prediction of impacts on air quality, started with emission inventory to calculate emission rate of pollutants generated from project activities during construction and operation phase, continue with prediction of impacts on air quality due to generation of air pollutants using modelling tool. Results of air pollutant inventory shall be used as the emission rate input for the air quality modelling, and the output of modelling will give the description of predicted air pollutants during the construction and operation phase of the project.
- Description of assessment method, begins with calculation of emission rates, prediction of future ambient air quality using modelling tool, analyse modelling output and impacts to the surrounding area of the projects as well as to the sensitive receptors.

2.1 Data Collection and Calculation

2.1.1 Air Quality Background Concentration and Meteorological Data

Measurement of Air Quality Background Concentration

Measurement of air quality parameters was conducted in selected sampling points in order to have the description of air quality background concentration around the project area. Seven air quality parameter, i.e. PM_{10}, $PM_{2.5}$, carbon monoxide (CO), nitrogen dioxide (NO_2), sulphur dioxide (SO_2), ozone, and hydrocarbon were measured using international standard method as shown in **Table 2.1**.

Table 2.1 Sampling Location and Method for Collecting Primary Air Quality Data

No.	Location	Sampling Method	Sampling Duration	Equipment
1.	PM_{10}	Gravimetric method, Japan International Standard (JIS) No. Z 8814 1994	24 hours	Low Volume Sampler
2.	$PM_{2.5}$			
3.	Carbon Monoxide	Iodine Pentoxide Method	1 hour	Midget Impinger, Spectrophotometry,
4.	Nitrogen Dioxide	Griess Saltzman Method, ASTM D1607 - 91(2011).	1 hour	Midget Impinger, Spectrophotometry,
5.	Sulphur Dioxide	Pararosaniline Method, ASTM 2914 (2007)	1 hour	Midget Impinger, Spectrophotometry,

[1] Background" can be defined as concentrations of chemicals in the atmosphere, in the immediate area of an environmentally impacted site. Background concentrations can be naturally occurring (i.e., the concentration is not due to a release of chemicals from human activities), or anthropogenic (i.e., the presence of a chemical in the environment is due to human activities, but is not the result of site-specific use or release of waste or products, or industrial activity).

No.	Location	Sampling Method	Sampling Duration	Equipment
6	Ozone	Methods of Air Sampling and Analysis, 1989	1 hour	Midget Impinger, Spectrophotometry,
7.	Hydrocarbon	NIOSH 1501, 2003	3 hours	Absorber, Gas Chromatography

PM_{10} and $PM_{2.5}$

The PM_{10} and $PM_{2.5}$ were measured using Japan International Standard (JIS) no. Z 8814 1994. This Japanese Industrial Standard specifies low volume air sampler of the suction capacity not more than 30 l/minute and has grading capacities out of the air samplers which is used for measurement of mass concentration of airborne dust. The sampler consists of a grading device, filter, holder, flow meter and an suction pump, as shown in **Figure 2.1.**

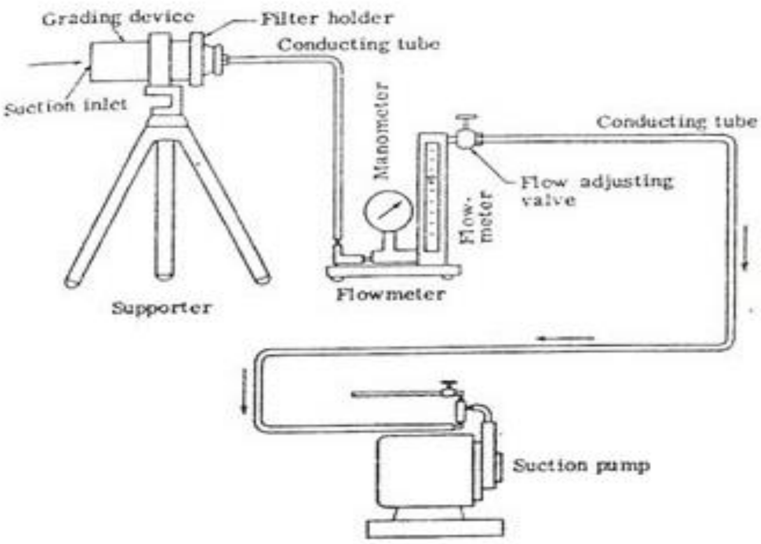


Figure 2.1 Arrangement of Low Volume Sampler for Measuring Ambient PM_{10} Concentration

This method provides for the measurement of the mass concentration of particulate matter with an aerodynamic diameter less than or equal to a nominal 10 micrometers (PM_{10}) in ambient air over a 24-hour period. The measurement process is non-destructive, and the PM_{10} sample can be subjected to subsequent physical or chemical analyses. Using this method, an air sampler draws ambient air at a constant flow rate into a specially shaped inlet where the suspended particulate matter is inertially separated into one size fractions within the PM_{10} size range. Each filter is weighed (after moisture equilibration) before and after use to determine the net weight (mass) gain due to collected PM_{10}. The total volume of air sampled, corrected to reference conditions (25^{o}C, 1 atm), is determined from the measured flow rate and the sampling time. The mass concentration of PM_{10} in the ambient air is computed as the total mass of collected particles in the PM_{10} size range divided by the volume of air sampled, and is expressed in micrograms per cubic meter (µg/m^3).

Carbon Monoxide (CO)

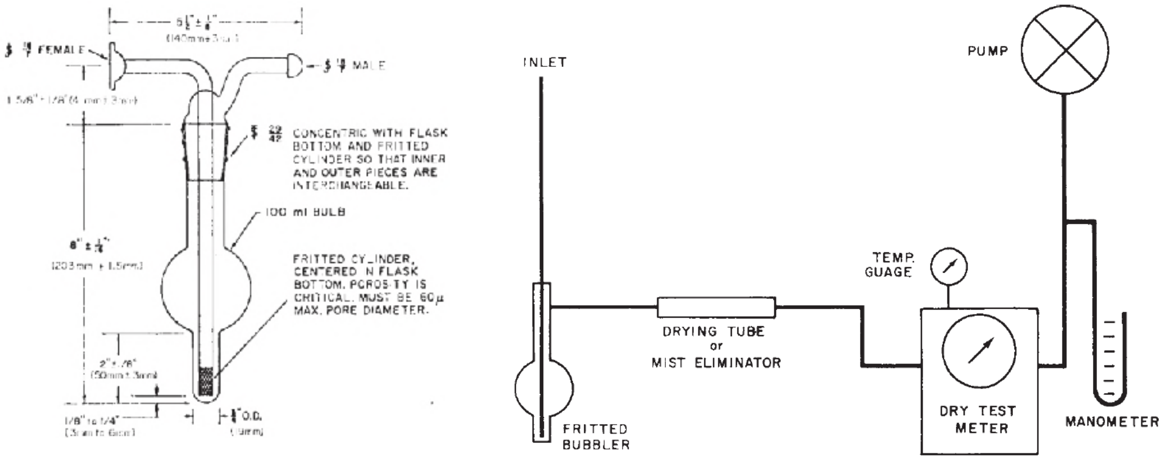
Carbon monoxide was measured using the iodine pentoxide method. The determination consists basically of the passage of a known volume of the gas to be analysed, first through a purifying and drying train, and then a heated tube of iodine pentoxide. Iodine and carbon dioxide are formed in amounts proportional to the quantity of carbon monoxide in the sample, according to the reaction

$$I_2O_5 + 5CO \rightarrow I_2 + CO_2$$

Either the liberated iodine or the carbon dioxide formed may be determined. Where the carbon monoxide concentration is low (0-50 ppm) the iodometric finish is more sensitive and allows smaller gas samples to be used. Concentration of carbon monoxide of the order of 1-2 ppm can be determined.

Nitrogen Dioxide (NO_2)

The ambient nitrogen dioxide concentration was measured using Griess-Saltzman method according to ASTM D1607 - 91(2011), with sampling systems described in **Figure 2.2**. The NO_2 is absorbed in an azo-dye-forming reagent; a red-violet color is produced within 15 min, the intensity of which is measured spectrophotometrically at 550 nm. This test method covers the manual determination of nitrogen dioxide (NO_2) in the atmosphere in the range from 4 to 10 000 µg/m^3 (0.002 to 5 ppm(v)) when sampling is conducted in fritted-tip bubblers. The maximum sampling period is 60 min at a flow rate of 0.4 L/min.



(a). Fitted Buller for Sampling Nitrogen Dioxide

(b). Sampling Train

Figure 2.2 Sampling System for Measuring Ambient NO_2 Concentration

Sulphur Dioxide (SO_2)

Ambient SO_2 concentration was determined using West Gaeke method according to ASTM 2914 (2007), the sampling system is described in **Figure 2.3**. The SO_2 is absorbed by aspirating a measured air sample through a tetrachloromercurate (TCM) solution, resulting in the formation of a dichlorosulfonatomercurate complex**.** Ethylenediaminetetraacetic acid disodium salt (EDTA) is added to this solution to complex heavy metals that interfere with this method**.** Dichlorosulfonatomercurate, once formed, is stable to strong oxidants (for example, ozone and oxides of nitrogen)**.** After the absorption is completed, any ozone in the solution is allowed to decay**.** The liquid is treated first with a solution of sulfamic acid to destroy the nitrite anion formed from the absorption of oxides of nitrogen present in the atmosphere**.** It is treated next with solutions of formaldehyde and specially purified acid-bleached pararosaniline containing phosphoric acid (H_3PO_4) to control pH. Pararosaniline, formaldehyde, and the bisulphite anion react to form the intensely colored pararosaniline methyl sulphonic acid which behaves as a two-colour pH indicator**.** The pH of the final solution is adjusted to the desired value by the addition of prescribed amounts of 3 N H_3PO_4 to the pararosaniline reagent. These test methods are applicable for determining SO_2 over the range from approximately 25µg/m^3 (0.01 ppm(v)) to 1000µg/m^3 (0.4 ppm(v)), corresponding to a solution concentration of 0.03 g SO_2/mL to 1.3 g SO_2/mL. Beer's law is followed through the working analytical range from 0.02 g SO_2/mL to 1.4 g SO_2/mL. These test methods incorporate sampling for periods between 30 min and 24 h.

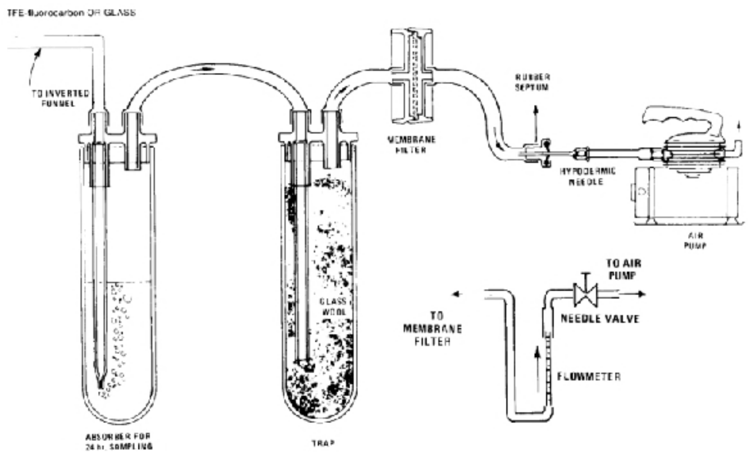


Figure 2.3. Sampling System for Measuring Ambient SO_2 Concentration

Ozone

Ozone was measured by micro-amounts of ozone and other oxidants liberate iodine when absorbed in a 1% solution of potassium iodide buffered at pH 6.8 ± 0.2. The iodine is determined spectrophotometrically by measuring the absorption of triiodide ion at 352nm. The stoichiometry is approximated by the following reaction:

$$O_3 + 3KI + H_2O = KI_3 + 2\ KOH + O_2$$

This method covers the manual determination of oxidant concentrations between 0.01 to 10 ppm (19.6 to 19.620 µg/m^3) as ozone.

Hydrocarbon

Non-methane hydrocarbon was determined using method published by NIOSH 1501, 2003. A solid sorbent tube contain of certain absorber in a glass tube sampler were exposed to the air flow at 0.01 to 1 L/min for 3 hours. The absorbed gases were then determined using gas chromatography.

Collection of Meteorological Data

Primary meteorological data were taken during measurement of air quality background concentration. These primary data were useful for correction of concentration of air quality parameter at standard temperature and pressure. Concentration at standard temperature and pressure can be compared to any international air quality standard. Secondary data of daily meteorological data particularly wind speed and direction, rainfall, temperature, pressure, and cloud cover, were collected from Baucau weather station which is located in Baucau District at 8°28'12.00" South and 126°27'0.00" East World Geodetic System 84 coordinate. Other additional secondary meteorological data were also collected from *www.weblakes.com* which provides hourly meteorological data all around the world.

2.1.2 Prediction of Impacts on Air Quality

2.1.2.1 Emission Inventory of Air Pollutants Generated from Project Activities

During the construction and operation phase of the cement plant, there shall be activities which will contribute to the emission of air pollutants to the ambient air. These mainly related to the following activities:

- Construction phase, include: site preparation, the use of construction equipment during construction phase, and mobilization of materials and equipment
- Operation phase, include: mining activities, plant operation, and mobilization of raw materials

Emission factor calculation can be applied to quantify the level of each air quality parameter emission rates from each specified activity. An emissions factor is a representative value that attempts to relate the quantity of a pollutant released to the atmosphere with an activity associated with the release of that pollutant. These factors are usually expressed as the weight of pollutant divided by a unit weight, volume, distance, or duration of the activity emitting the pollutant. In most cases, these factors are simply averages of all available data of acceptable quality, and are generally assumed to be representative of long-term averages for all facilities in the source category i.e., a population average (www.epa.gov). The general equation for emissions estimation using emission factors are:

$$E = A \times EF \times (1 - ER/100)$$

Where:
E = emissions (in mass of PM_{10} per year)
A = activity rate (unit depends on the emission factor's unit)
EF = emission factor (units are various)
ER = overall emission reduction efficiency, %

The form of the formula might change in a more complex way, usually because of the detail calculation of the activities. The level of accuracy shall also depend on the availability data of the site specific activities. The followings are the anthropogenic activities during the construction and operational phase of cement plant which may contribute to emit additional air pollutants to the ambient air.

- **Site Preparation**

  Earth moving activities during construction and wind erosion are sources of PM_{10} and $PM_{2.5}$ emissions. PM_{10} and $PM_{2.5}$ emissions caused by earth moving and wind erosion may be calculated using the methodologies outlined in Section 13.2.3 "Heavy Construction Operations" of A-42. All possible emission factors are shown in **Table 2.2**.

Table 2.2. Emission Factor for Activity Related to Site Preparation

Construction Phase	Dust Generating Activities	Emission Factor	Unit	Source
Site preparation	Bulldozing (top soil)	PM_{10}: : $0.75 \frac{18.6\,(s)^{1.5}}{(M)^{1.4}}$ $PM_{2.5}$: $0.022 \frac{78.4\,(s)^{1.2}}{(M)^{1.3}}$	Kg/hour	AP.42 Sec.13.2, Table 13.2.3
	Loading of excavated	$k * 0.0016 * \frac{(\frac{U}{2.2})^{1.3}}{(\frac{M}{2})^{1.4}}$	Kg/Mg	Ap.42

Construction Phase	Dust Generating Activities	Emission Factor	Unit	Source
	material into trucks Truck dumping of fill material, road base or other materials	k=0.35 for PM_{10},& 0.053 for $PM_{2.5}$		Sec. 13.2.4
	Active storage pile (emission due to wind erosion and maintenance	∗0.85 for TSP	Mg/ (hectare) /year	Ap.42 Sec.11.9, Table 11.9.2

- **Mobilization of Vehicles during Construction and Operational Phase**

Particulate emissions from paved and unpaved roads are due to direct emissions from vehicles in the form of exhaust, brake wear and tire wear emissions and re-suspension of loose material on the road surface. In general terms, re-suspended particulate emissions from paved roads originate from, and result in the depletion of the loose material present on the surface. The quantity of particulate emission factor from re-suspension of loose material on the road surface due to vehicle travel on a dry paved road and unpaved road may be estimated using the empirical expression as shown in **Table 2.3**. The emission of concern from paved and unpaved roads is particulate matter (PM) including PM less than 10 microns in aerodynamic diameter (PM_{10}) and PM less than 2.5 microns in aerodynamic diameter ($PM_{2.5}$).

Table 2.3 Emission Factor Mobilization of Vehicles during Construction and Operation Phase

Dust Generating Activities	Emission Factor	Unit	Source
Paved road	$E = k * (sL)^{0.9} * (W)^{1.02}$ k = 0.62 for PM_{10} & k =0.15 for $PM_{2.5}$	g/VKT	Ap.42 Sec.13.2.1
Unpaved road	$E = k\ 5.9 \left(\frac{s}{12}\right)\left(\frac{S}{30}\right)\left(\frac{W}{3}\right)^{0.7}\left(\frac{w}{4}\right)^{0.5}\left(\frac{365-p}{365}\right)$ K = 0.36 for PM_{10}, and 0.095 for $PM_{2.5}$	lb/VMT, (1lb/VMT = 281.0 g/VKT)	Ap.42 Sec.13.2.2

Note: Source: AP42 USEPA (www.epa.gov), sec. 13.2.3 Heavy Construction Operation

s = material silt content (%), between 0.44-19%,
K = particle size multiplier (dimensionless)
U = mean wind speed, m/s
M = material moisture content (%), between 0.25-4.8%
sL = road surface silt loading (g/m^2), between 0.03-400 g/m^2
W = average weight of the vehicles travelling the road (ton)
S = mean vehicle speed (mph)
w = mean number of wheels (dimensionless)
p = number of days with at least 0.254 mm of precipitation per year

The quantity of dust emissions from a given segment of unpaved road varies linearly with the volume of traffic. Field investigations also have shown that emissions depend on correction parameters that characterize (a) the condition of a particular road and (b) the associated vehicle traffic. Parameters of interest in addition to the source activity (number of vehicle passes) include the vehicle characteristics (e.g., vehicle weight), the properties of the road surface material being disturbed (e.g. silt content, moisture content), and the climatic conditions (e.g., frequency and amounts of precipitation). Dust emissions from unpaved roads have been found to vary directly with the fraction of silt in the road surface material. Silt consists of particles less than 75 µm in diameter, and silt content can be determined by measuring the proportion of loose dry surface dust that passes through a 200-mesh screen, using the ASTM-C-136 method.

Besides emission of particulates, gases are also emitted from the combustion of fuels during mobilization of vehicles. Emission factors for calculating the emission rates are derived from the Air Resources Board of California USA which develop the emission factor by taking the weighted average of vehicle types and simplifying them into three categories – passenger/light-duty (< 8,500 pounds) and medium-/heavy-duty vehicles (e.g., delivery trucks, > 8,500 pounds), and heavy duty (33,0001 to 60,000 pounds as shown in **Table 2.4**.

Table 2.4 Emission Factors for Mobilization of Vehicles during Construction and Operation Phase

No	Parameter	Emission factor (pounds/mile)		
		Passenger Vehicles (< 8,500 pounds)	**Delivery Trucks (>8,500 pounds)**	**Heavy-Heavy Duty Diesel Trucks (33,001 to 60,000 pounds)**
1	PM_{10}	0.00009	0.00050	0.00105
2	$PM_{2.5}$	0.00006	0.00041	0.00088
3	CO	0.00614	0.01169	0.00767
4	NO_x	0.00060	0.01285	0.02123
5	SO_x	0.00001	0.00003	0.00004

Source : *http://www.aqmd.gov/home/regulations/ceqa/air-quality-analysis-handbook/emfac-2007-(v2-3)-emission-factors-(on-road)*, model year 2015

- **Operation of Heavy Equipment During Construction and Operation Phase**

Construction equipment emissions estimates are generally developed using two basic methodologies (non-road and on road) depending on the type of construction equipment. Non road construction equipment (e.g., bulldozers, backhoes, front end loaders, etc.) are generally operated off road and on the construction site. On road construction equipment (e.g., semi-trucks for material hauling), in contrast can be operated on public roads. Non road estimation methods which are described in the USEPA report, *Non road Engine and Vehicle Emission Study—Report* are able to be used for construction activities which would require heavy duty construction equipment.

Air pollutants in the form of particulates and gases emitted by operation of heavy equipment are mainly because of the results of combustion of fuels. The amounts of emitted pollutants are calculated based on various emission factors (**Table 2.5, 2.6, and 2.7**) in unit of gram/hour or gram/bhp-hour, and various activities data information such as operational hours and engine power.

Table 2.5 Emission Factor for Equipment Activities during Construction Phase

No	Equipment	Requirement for Each Location					Con-dition	Emission Factor									
		Jetty	Plant	Lime stone Mine	Clay Mine	Stock pile		TOG	VOC	CO	NO_x	SO_2	PM_{10} paved	$PM_{2.5}$ paved	PM_{10} unpaved	$PM_{2.5}$ unpaved	Unit
1	Water truck/fuel truck, MHDT						idle		3.17	26.30	75.05	0.04	0.53	0.49	0.53	0.49	g/hr
		2	5				On site		0.39	4.62	7.31	0.01	1.88	0.36	2.41	0.47	g/hr
2	Pile driving rig	2	2														
3	Crane	2	5				175 HP	0.830		3.410	5.100	0.006	0.260	0.239			g/bhp-hr
4	Low & Flat bed trailer, HHDT	2	5				idle		10.78	45.96	114.93	0.06	0.76	0.70			
							On site		4.83	10.14	19.56	0.03	2.30	0.72	2.83	0.82	g/hr
5	Prime mover and or self propelled transporter with power pack		2														
6	Fork lift		3				175	0.661		3.353	4.320	0.006	0.249	0.229			g/bhp-hr
7	Welding generators		5				50	2.441		6.028	5.549	0.007	0.525	0.483			
8	Excavator			3	1		175	0.696		3.377	4.523	0.006	0.259	0.239			g/bhp-hr
9	Bulldozer / Ripper			1	1	3	500	0.784		3.053	4.700	0.006	0.140	0.129			g/bhp-hr
10	Dump Truck, HHDT			7	4		Idle		10.78	45.96	114.93	0.06	0.76	0.70	0.76	0.70	g/hr
							On site		4.83	10.14	19.56	0.03	2.30	0.72	2.83	0.82	g/hr
11	Motor Grader			1			175	0.766		3.369	5.100	0.006	0.260	0.239			g/bhp-hr
12	Wheel Loader					5	250	0.430		1.194	2.800	0.006	0.109	0.100			g/bhp-hr
13	Power generators	1	1				229		0.44	1.27	3.87	0.01	0.13	0.12			g/bhp-hr

Source: - http://www.fhwa.dot.gov/environment/air_quality/conformity/methodologies/emfac.cfm
- www.portoflosangeles.org/EIR/SCIG/DEIR/APPENDIX_C1.pdf

Note : The number of equipment is based on similar project of cement factory and or assumption of the expert.

Table 2.6 Emission Factor for Equipment Activities during Operation Phase of Limestone Mine

No	Activity Data (A)								Emission Factor (EF)					
	Equipment	Capa-city	Require-ment	Condi-tion	Capacity		Operating hours	Vehicle Mile Travel	PM_{10}	$PM_{2.5}$	CO	NO_x	SO_2	Unit
			R		Cap		OH	VMT	EF					
					bhp	bhp	hours/year	Mile/year						
1	**Main Maining Equipment**													
1.1	Drilling machine	385 Hp	3		385	379.61	3300		0.259	0.239	3.377	4.523	0.006	g/bhp-hr[a]
1.2	Excavator with rock breaker	40 ton class, 175 Hp	1		175	172.55	3300		0.259	0.239	3.377	4.523	0.006	g/bhp-hr[a]
2	**Loading**													
2.1	Hydraulic excavator	4.5 m^3 bucket cap., 450 Hp	3		175	172.55	3300		0.259	0.239	3.377	4.523	0.006	g/bhp-hr[a]
2.2	Loader	4 m^3 bucket, 350 Hp	1		250	246.5	3300		0.109	0.1	1.194	2.8	0.006	g/bhp-hr[a]
3	**Transportation**													
3.1	Off highway dump truck, HHDT	36 ton payload cap., 450 Hp	2	Idle			330		0.76	0.7	45.96	114.93	0.06	g/hr[a]
			8	On site			2970		2.3	0.72	10.14	19.56	0.03	g/hr[a]
4	**Ancillaries**													
4.1	Bulldozer with ripper	300 – 350 Hp	1		350	345.1	3300		0.14	0.129	3.053	4.7	0.006	g/bhp-hr[a]

No	Activity Data (A)								Emission Factor (EF)					
	Equipment	Capa-city	Require-ment	Condi-tion	Capacity		Operating hours	Vehicle Mile Travel	PM_{10}	$PM_{2.5}$	CO	NO_x	SO_2	Unit
			R		Cap		OH	VMT	EF					
					bhp	bhp	hours/year	Mile/year						
4.2	Grader	140 – 150 hp	1		150	147.9	3300		0.26	0.239	3.369	5.1	0.006	g/bhp-hr[a]
4.3	Jeeps - Double Axle drive		2					36,828	5.0E-04	4.1E-04	1.2E-02	1.3E-02	3.E-05	pounds/mile[b]
4.4	Water sprinkler (truck chassis mounted)		1					17,820	5.0E-04	4.1E-04	1.2E-02	1.3E-02	3.E-05	pounds/mile[b]
4.5	Fuel tanker (truck chassis mounted)		1					17,820	5.0E-04	4.1E-04	1.2E-02	1.3E-02	3.E-05	pounds/mile[b]
4.6	Mobile service van		1					36,828	9.3E-05	6.0E-05	6.1E-03	6.0E-04	1.E-05	pounds/mile[b]

Source: -[a] http://www.fhwa.dot.gov/environment/air_quality/conformity/methodologies/emfac.cfm

- [a]www.portoflosangeles.org/EIR/SCIG/DEIR/APPENDIX_C1.pdf
- [b]http://www.aqmd.gov/home/regulations/ceqa/air-quality-analysis-handbook/emfac-2007-(v2-3)-emission-factors-(on-road)

Note : The number of equipment is based on similar project of cement factory and or assumption of the expert.

Table 2.7 Emission Factor for Equipment during Operation Phase of Clay Mine

No	Activity Data							Emission Factor (EF)					
	Equipment	Cap	Requirement	Capacity		Operating Hour	Vehicle mile travel	PM_{10}	$PM_{2.5}$	CO	NO_x	SO_2	Unit
			R	Cap		OH	VMT	EF					
				HP	BHP	hour/year	mile/year						
1	Hydraulic excavator	3 m^3	1	175	172.55	3300		0.259	0.239	3.377	4.523	0.006	g/bhp-hr[a]
2	Tippers	10 ton	20				41,450	5.0E-04	4.1E-04	1.2E-02	1.3E-02	3.E-05	pounds/mile
3	Water sprinkler (truck chassis mounted)		1				12,435	5.0E-04	4.1E-04	1.2E-02	1.3E-02	3.E-05	pounds/mile
4	Fuel tanker (truck chassis mounted)		1	175			12,435	5.0E-04	4.1E-04	1.2E-02	1.3E-02	3.E-05	pounds/mile

Source: -[a] http://www.fhwa.dot.gov/environment/air_quality/conformity/methodologies/emfac.cfm

- [a]www.portoflosangeles.org/EIR/SCIG/DEIR/APPENDIX_C1.pdf

- **Cement Plant Operation**

Emissions from cement plant operation as shown in **Figure 2.4** can be broadly divided into five stages:

- ***Quarrying of raw materials*** (limestone and mine quarrying),

  Particulates are mainly emitted from the activity of land clearing, blasting, loading and handling extracted material, material stockpile and material transportation.

- ***Raw material handling***

  Activities during raw material handling, e.g. crushing, transferring, stockpiling, area the main sources of particulate emission

- ***Pyro processing to produce clinker***

  The production of clinker takes place in a kiln system in which the minerals of the raw mix are transformed at high temperatures into new minerals with hydraulic properties. The fine particles of the raw mix move from the cool end to the hot end of the kiln system and the combustion gases move the other way from the hot end to the cold end. This results in an efficient transfer of heat and energy to the raw mix and an efficient removal of pollutants and ash from the combustion process.

- ***Cement mill to produce cement***

  The final step in cement manufacturing involves a sequence of blending and grinding operations that transforms clinker to finished Portland cement. Up to 5 percent gypsum is added to the clinker during grinding to control the cement setting time, and other specialty chemicals are added as needed to impart specific product properties. This finish milling is accomplished almost exclusively in ball or tube mills. Typically, finishing is conducted in a closed circuit system, with product sizing by air separation

- Storage, packing, and delivery of cement

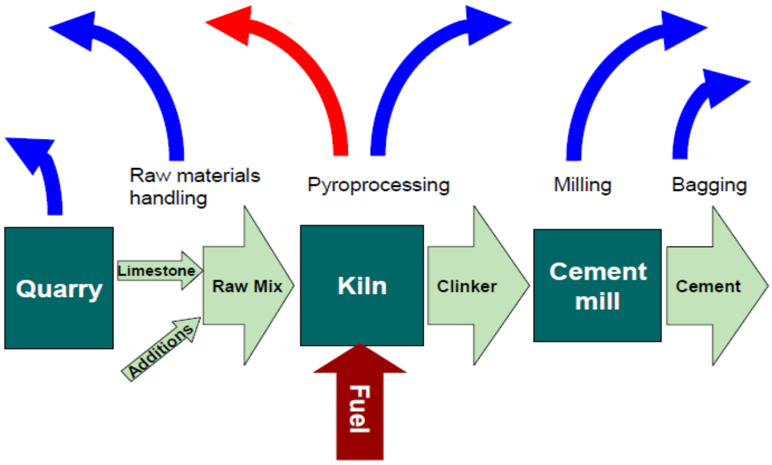


Figure 2.4 Emission of Cement Production, Combustion emissions are indicated in red, process emissions are indicated in blue (Source: EMEP/EEA, 2013)

Emission factors for calculating air pollutant emissions from cement production are described in **Table** below.

Table 2.8 Emission Factors for Quarrying Activities in Cement Production

No	Activity			Emission Factor				Source
				TSP	PM_{10}	$PM_{2.5}$	Unit	
1.1	*Limestone mining* *Size: (*2347.15 m x 2446.07 m)							
	Land clearing	Overburden	Bulldozing	$\frac{2.6\,(s)^{1.2}}{(M)^{1.3}}$	$0.75\,\frac{0.45\,(s)^{1.5}}{(M)^{1.4}}$	$0.105\,\frac{2.6\,(s)^{1.2}}{(M)^{1.3}}$	kg/hour	AP.42 Sec.13.2, Table 13.2.3
								AP 42 Sec 11.9, Table 11.9.2
	Truck load/ unloading	Overburden		10^{-3}				AP 42 Sec 11.9, Table 11.9.4
	Blasting	Overburden/ limestone	1 to 2 times a week		$0.00022\,(A)^{1.5}$ PM10k=0.52, PM 2.5k=0.03		Kg/blast	AP 42 Sec 11.9, Table 11.9.2
	Drilling	Limestone			$4*10^{-5}$		kg/Mg	AP 42 Sec 11.9.2 Table 11.9.2-1
	Loading and handling		Transferred material		$k * 0.0016 * \frac{(\frac{U}{2.2})^{1.3}}{(\frac{M}{2})^{1.4}}$ PM10: k=0.35, PM 2.5: k=0.053		kg/Mg	AP 42 Sec. 13.2.4
	Limestone transportation		Calculated as mobile sources					
1.2	*Clay mining*							
	Land Clearing		Bulldozing	$\frac{2.6\,(s)^{1.2}}{(M)^{1.3}}$	$0.75\,\frac{0.45\,(s)^{1.5}}{(M)^{1.4}}$	$0.105\,\frac{2.6\,(s)^{1.2}}{(M)^{1.3}}$	kg/hour	AP.42 Sec.13.2, Table 13.2.3
	Blasting		**2 to 3 times a week**					
	Clay stockpile		Wind erosion					

Note: - De-dusting bag filters for dust suppression system
- All transfer points shall be properly de-dusted
- The nuisance bag filters for equipment shall ensure dust emission level of 30 mg/ Nm^3.

Main emission from stacks during operation phase come from the kiln, cooler ESP, cement mill, coal mill, and thermal power plant. **Table 2.9** shows the characteristics of the stack and its emission concentration.

Table 2.9 Emission Factors for Other Point Sources

No	*Point Source*	*Stack Diameter* D m	*Stack Height* H m	*Gas Stack Tem-perature* T Celsius	*Velo-city* v m/s	*Output concentration* C PM_{10} mg/Nm^3	SO_2	NO_x	CO
1	Kiln/Raw mill bag House stack	4	120	120	18	30	200	800	500
2	Cooler ESP stack	3.4	35	110	18	30			
3	Cement Mill bag House Stack	1.5	55	90	18	30			
4	Coal Mill Bag House Stack	2	65	77.5	18	30			
5	Thermal Power plant Stack	2.5	90	140	18	30	200	800	500

2.1.2.2 Prediction of Future Air Quality using Modelling Tool

After calculating the emission rate of each air pollutants from all activities during cement plant construction and operation phase, the air quality modelling shall be conducted to predict the quality of ambient air both in the construction phase and operation phase.

This study use ISC AERMOD View for predicting the impact to the air quality. The AERMOD is a steady state gaussian plume model that is appropriate for estimating impact for short-range transport for distance less than 50 kilometers (km). Other models are also available such as RAMS, a mesocale model, which is capable of modelling weather system such as land/sea and mountain circulation and suitable to model meteorological condition in a complex coastal area. Another well-known model is CALFUFF, a non-steady-state lagrangian gaussian puff model, which is recommended to be used for modelling impact with distances greater than 50 km, and the use on case by case basis in complex flow situation for shorter distances.

ISC AERMOD VIEW model was chosen for calculating the air quality impact due to the following reasons:

- Modelling area is less than 50 km, a short range transport model (AERMOD) should be more suitable than a long range transport model (RAMS or CALPUFF)
- Limited meteorological data available in Baucau.

  Recorded meteorological data from Baucau Meteorological Station cannot represent the specific onshore-offshore recirculation because each day it only recorded the meteorological condition at 9:00, 15:00 and 18:00 East Timor Time.
- Previous studies comparing AERMOD and RAMS. AERMOD and CALPUFF give the following results:

- Modelling study to compare AERMOD and RAMS showed that both models configuration predicted very similar short term average concentration when using identical input data (Borrego and Incecik, 2004).
- According to Rood (2014),
  - Framework of a Lagrangian puff model is better suited for long range compared to the steady-state models.
  - The steady-state models generally did not underestimate the high-end concentrations at the distances studied, and therefore provide a sound basis for regulatory compliance modeling. Based on the overall performance, assessment models that rely on the Gaussian plume (e.g. AERMOD) model are not necessarily inferior to the current state-of-the-art models (e.g. Calpuff) in terms of meeting regulatory performance objectives.
  - The need for consistency and assurance that estimated concentrations are not underestimated are legitimate reasons for using steady-state models for regulatory compliance determination.
  - Another compelling reason to use steady-state models for regulatory compliance demonstration is the fact that they are simpler to run, require less user judgment, and are less prone to error than Lagrangian puff models.

2.1.3 Impact Assessment Method

The impact assessment on air quality consists of the following steps:

- Calculate the emission rates of air pollutants during construction and operation phase using emission inventory method;
- Predict the future ambient air pollutant concentration using AERMOD VIEW Software, utilize calculated emission rates and collected Baucau meteorological data for the modelling input;
- Present the modelling results in the form of isopleth concentration of 1st high 1 hour concentration, 1st high 24 hour concentration, and 1st high annual concentration;
- Compare calculated ambient concentration with the international standard, analyse the dispersion pattern as well as impacts to the sensitive receptors.

  The ambient air quality parameter either as the result of primary measurement (baseline data) or prediction using modelling shall be compared to the international standard as shown in **Table 2.10.**

Table 2.10. International Ambient Air Quality Standard

No.	Parameter	Time Average				Note
		1 hour	3 hour	24 hour	Annual	
1	PM_{10}			150[a]	70[a]	Interim Target (ITs -1)
2	$PM_{2.5}$			75[a]	35[a]	
3	CO	40000[b]				Not to be exceeded more than once per year
4	NO_2	200[a,c]			40[a,c]	
5	SO_2	350[c]		125[a]		
6	Ozone	235[d]				

No.	Parameter	Time Average				Note
		1 hour	3 hour	24 hour	Annual	
7	Hydrocarbon		160[e]			As non-methane hydrocarbon

Source:
[a] http://whqlibdoc.who.int/hq/2006/WHO_SDE_PHE_OEH_06.02_eng.pdf
[b] http://www3.epa.gov/ttn/naaqs/criteria.html
[c] http://ec.europa.eu/environment/air/quality/standards.htm
[d] http://www.gpo.gov/fdsys/granule/CFR-2011-title40-vol2/CFR-2011-title40-vol2-sec50-9
[e] http://regulations.delaware.gov/AdminCode/title7/1000/1100/1103.shtml

According to guidance from European Union (2005), the ambient air quality standard for PM_{10} is 50 µg/m^3 for 24 hour-mean with permitted exceedance 35 times per year. In the final rule published by EPA on January 15, 2013, the PM_{10} standards was retained as no more than one exceedance of concentrations of 150 µg/m^3 per year on average over three years. In 2006, the World Health Organization (WHO) published global air quality guidelines (AQGs) for PM_{10} (WHO 2006; Krzyzanowski and Cohen 2008). Thus far, there have been four versions (WHO 1987, 2000a, b, 2006) of the World Health Organization Air Quality guidelines (WHO AQGs), the guidelines which provide an international reference that countries, particularly those without the resources to conduct their own assessment, can use to develop AAQSs. The 2006 WHO AQGs are composed of a single guideline value and interim targets (ITs). The interim targets provide a stepwise approach to achieving the air quality guideline value. The guideline values can be used by developed countries, with the capacity to implement a strict AAQS, while developing countries, with higher levels of air pollution, could select an interim target level achievable based on their own air quality management infrastructure, and progress towards the AQG value at their own pace. For standards which are not provided by WHO guideline, taken from United State Protection Agency (for CO, ozone, and hydrocarbon standard), and from European Commission for Environment (for NO_2 and SO_2 standard).

3. ENVIRONMENTAL BASELINE

3.1 Baucau Meteorological Data

Meteorological phenomena such as wind velocity, wind direction, temperature, pressure, as well as the cloud cover has a very close relation with the air quality as well as the calculation of air pollutant dispersion. The air movement (wind) and the exchange of heat (convection and radiation) dictate the fate of pollutants as they go through stages of reaction, transformation, dilution, dispersion, and transport. Knowledge of prevailing wind direction and its velocity also determine where the pollutants shall be dispersed. This is very essential in order to be able to identify places which undergo the highest exposure frequency to the dispersed air pollutants.

Meteorological data in Baucau were collected from Baucau Meteorological Station, located at 08° 28'12''S and 126° 27'0'' E with the altitude 451 m above the sea level. The collected data were in the form of average daily data from January 2014 until September 2014. These data are presented statistically in the form of average, minimum, and maximum data and or in the form of monthly average to show the gradual changes from time to time.

Figure 3.1 and **Figure 3.2** shows the daily data of relative humidity (%) and temperature (^{o}C) respectively, recorded from Baucau Meteorological Station. The humidity data tends to clearly decrease from January to September, and start to increase again from August to December. Highest relative humidly was recorded as high as 100% and lowest was recorded as low as 28%. Relative humidity indicates the ratio of the current absolute humidity to the highest possible absolute humidity (which depends on the current air temperature). A reading of 100 percent relative humidity means that the air is totally saturated with water vapour and cannot hold any more, creating the possibility of rain. This doesn't mean that the relative humidity must be 100 percent in order for it to rain, it must be 100 percent where the clouds are forming, but the relative humidity near the ground could be much less. The daily average temperature recorded as high as 31.8^{o}C (in November) and as low as 18.4^{o}C (in February). In general, as the temperature increases the relative humidity usually decreases or vice versa. Therefore, in September to November when the higher average of temperatures was observed, the humidity was recorded in the lower average.

From the daily and monthly precipitation data as shown in **Figure** 3**.3** and **Figure 3.4**, it is clearly showed that the wet season lasts from December to June while the dry season lasts from July to November. During the wet season, the highest rainfall was recorded in December (203 mm), while for the dry season the highest rainfall was in November (20 mm). There were many days, especially from July to October where there were no rain at all (0 mm/day). Those days may have the highest level of air pollution, since there will not be pollutant washout by rain through the wet deposition mechanism.

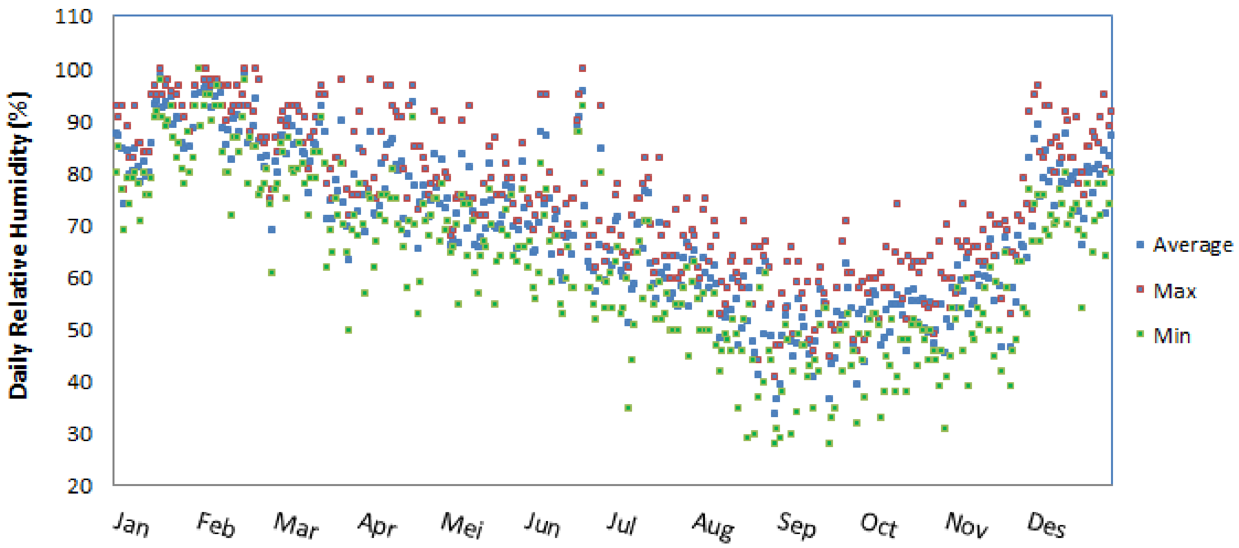


Figure 3.1 Daily Data of Relative Humidity

(Source: Baucau Meteorological Station)

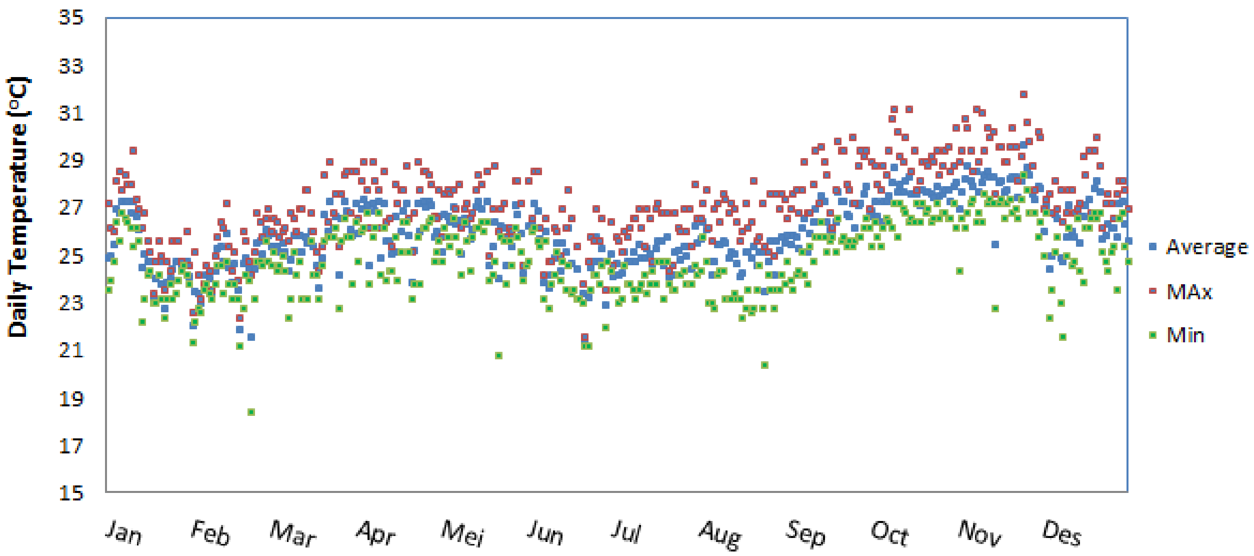


Figure 3.2 Daily Data of Temperature

(Source: Baucau Meteorological Station)

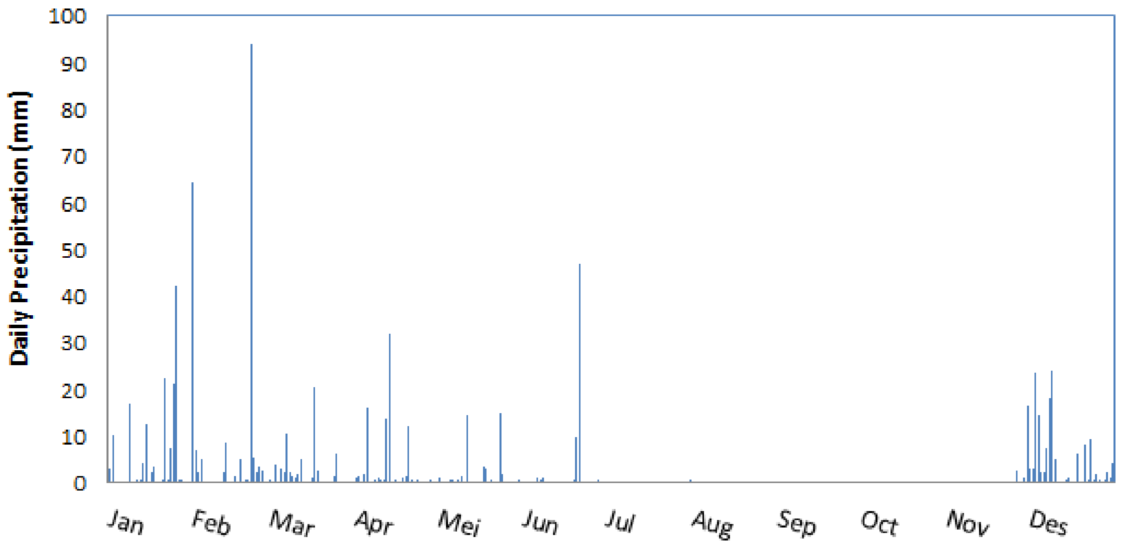


Figure 3.3 Daily Data of Precipitation

(Source: Baucau Meteorological Station)

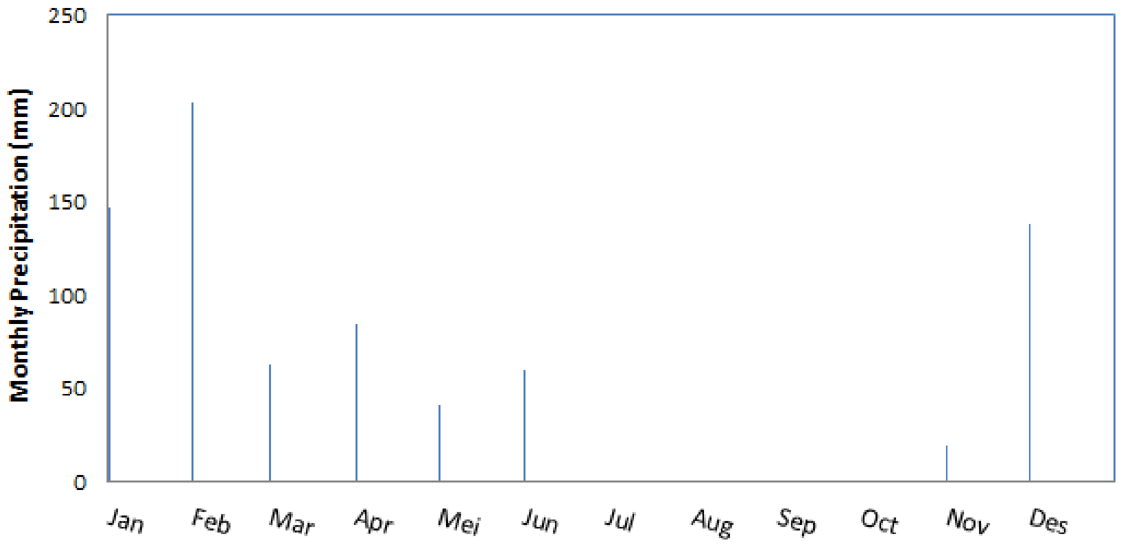


Figure 3.4 Monthly Data of Precipitation

(Source: Baucau Meteorological Station)

Meteorological data which include wind speed, wind direction, temperature, pressure, precipitation, and cloud cover are going to be used as input parameters in the air quality modelling using AERMOD VIEW software. Since this software requires hourly meteorological data for all parameters, other additional data which can supply these hourly data were collected from *www.weblakes.com*, The weblakes page provides meteorological data all around the world. Local meteorological data from Baucau meteorological station only provide daily average, minimum, and maximum data which were calculated from three times measurement at 9:00, 15:00, and18:00 East Timor Local Time. The availability data from this station cannot fulfil the requirement of the software, i.e., at least 99% hourly meteorological data should be available. This availability data is very important since it will strongly influence the accuracy of predicted ambient concentration.

A windrose diagrams which are shown in **Figure 3.5** to **Figure 3.9** illustrate summary of statistical information concerning direction and speed of the wind recorded from in Baucau Area using two data sources (Baucau meteorological station and *www.weblakes.com*). A line segment is drawn in each of sixteen compass directions from a common origin. The length of a particular segment is proportional to the frequency with which winds blow from that direction, while thicknesses of a segment indicate frequencies of occurrence of various classes of wind speed.

From this windrose diagram, it can be identified the prevailing wind directions, i.e., the direction from which the wind blows most frequently, not necessarily the direction from which the strongest wind comes. **Figure 3.5** shows the annual windrose diagram and denotes the prevailing winds most generally blow from South East to North West. Therefore it can be predicted that air pollutants shall most probably be dispersed to the opposite directions from the prevailing winds, i.e. the North East direction. Differences in wind rose pattern for these annual wind directions occur due to the difference of number of data source. Annual windrose from Baucau were generated from 3 sets hourly data for each day (only 1095 data), while annual windrose from *www.weblakes.com* were generated from 24 sets hourly data for each day (8760 data).

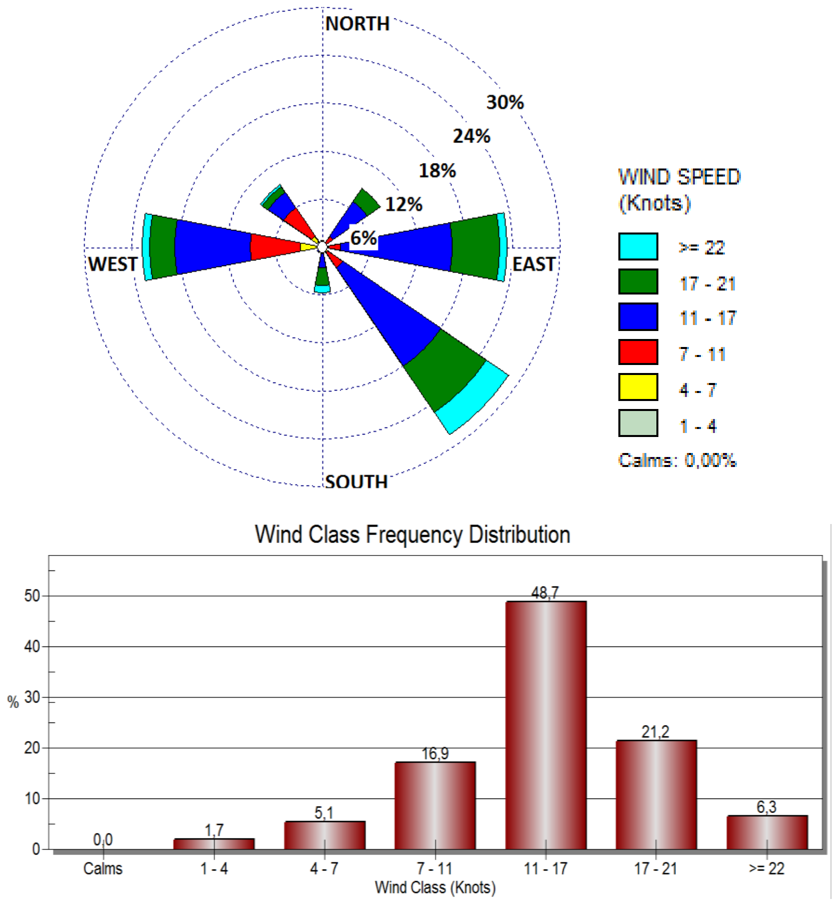
Figure 3.5 also indicates significant differences between wind speed data from Baucau meteorological station and from Weblakes. Wind speeds from Baucau are generally higher than weblakes, and this can be explained as follows:

- Windrose for Baucau station was generated from very limited data, i.e. wind speed at 9:00, 15:00. and 18:00 East Timor Time, or in total only 12.5% of total hourly data in a year (1095 data out of 8760 data). There are 87.5% missing data, especially data for night wind speeds. These missing data might consist of low wind speeds because the coastal wind speed during the night is generally lower than during the day.
- Windrose for Weblakes was generated from 8670 data, no missing data and data are available for either day wind speeds or night speeds.

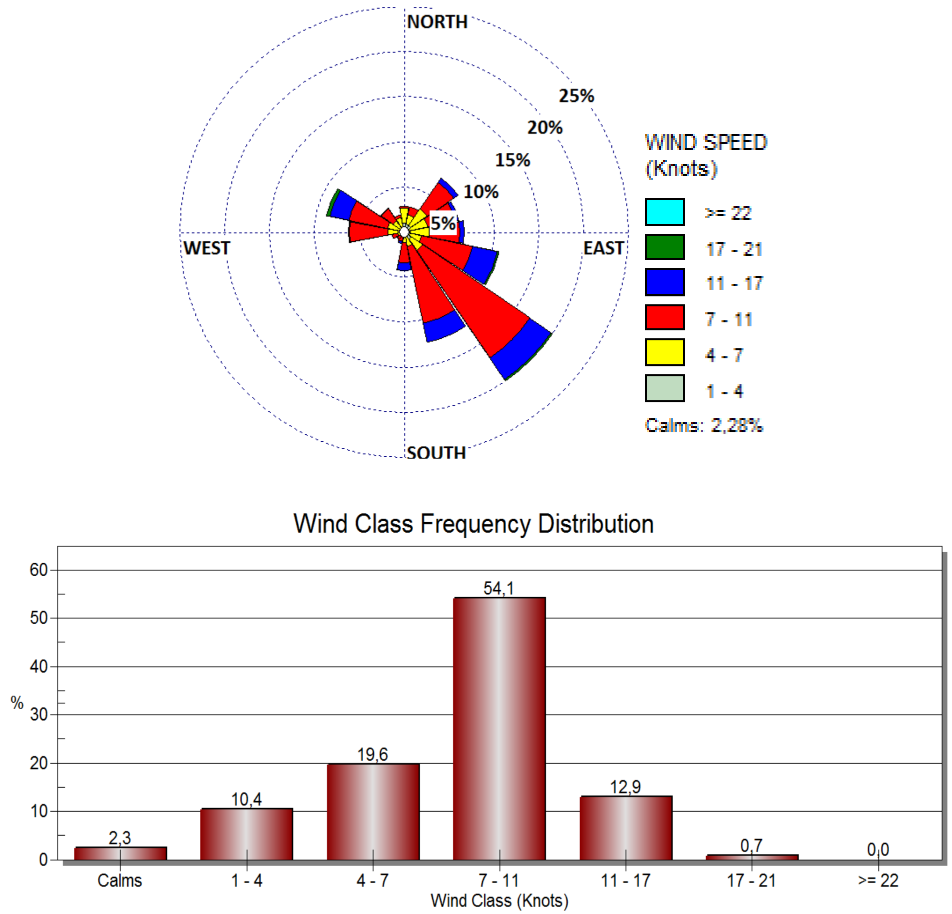
The wind class frequency distribution as shown in **Figure 3.5**, describes the range of wind speed which occurred in Baucau. The winds most frequently blow have the velocity range between 11 – 17 knots according to Baucau Meteorological Station (frequency of occurrence: 48.7%), and between 7 - 11 knots according to *www.weblakes.com* (frequency of occurrence 54.1%). Differences in the class of wind speed which most frequently occur from these two data source are also influenced by the difference number of data source.

The wind directions are mostly governed by local topography, onshore and offshore winds, or local mountains and valleys. Therefore it is also necessary to identify the gradual change of wind directions and velocity from month to month as shown from **Figure 3.6** until **Figure 3.9.** From January to March, the prevailing winds blow from West to East and North West to South East. In April occur changes in wind direction, and from May to August the wind are distinctly blow from South East to North West. In October the directions of prevailing winds start to change again, predominantly blow from West to East. In December the prevailing winds mostly blow from the opposite direction of wind that blows in November.

According to this behaviour of prevailing winds, the receptors that undergo the most frequent exposure to the air pollutant shall be those who live in North West of Baucau. These receptors may also have the highest probability to expose to the highest level of air pollutant concentration, since in the driest month (July - September), the prevailing winds also blow to this direction. Receptors that live in other directions may also expose to the emitted air pollutant, but in a lower frequency exposure.

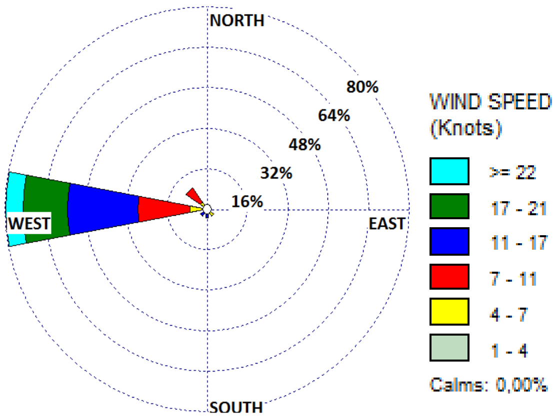


Source: Baucau Meteorological Station, 2014

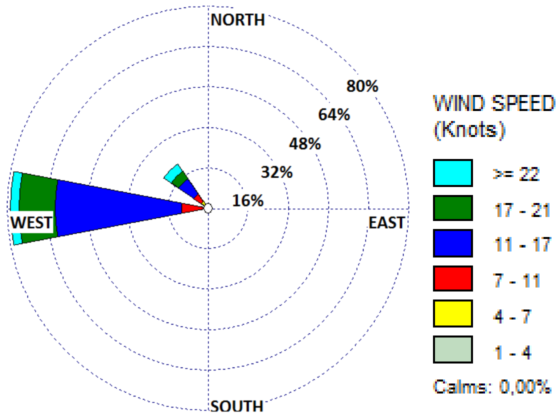


Source (www.weblakes.com, 2014)

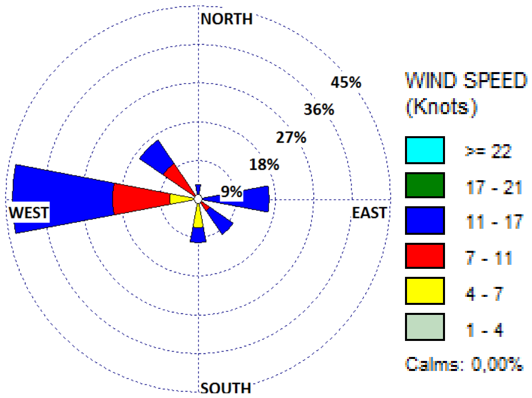
Figure 3.5 Annual Wind Rose and Wind Class Distribution Data



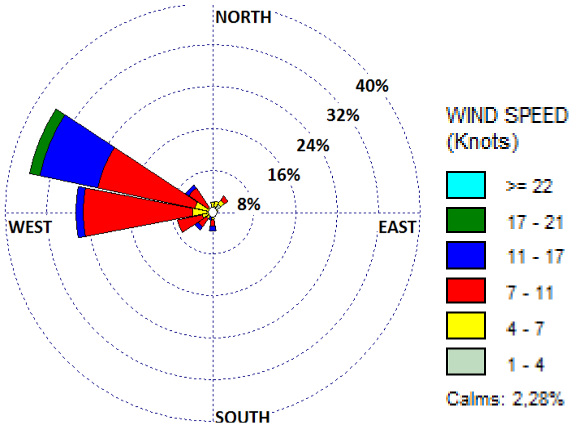
January (Baucau Meteorological Station)



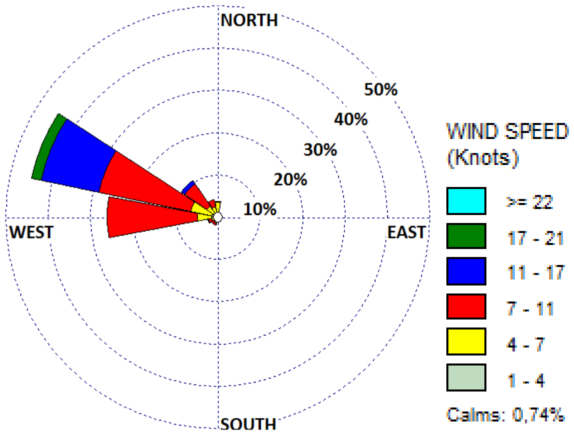
February (Baucau Meteorological Station)



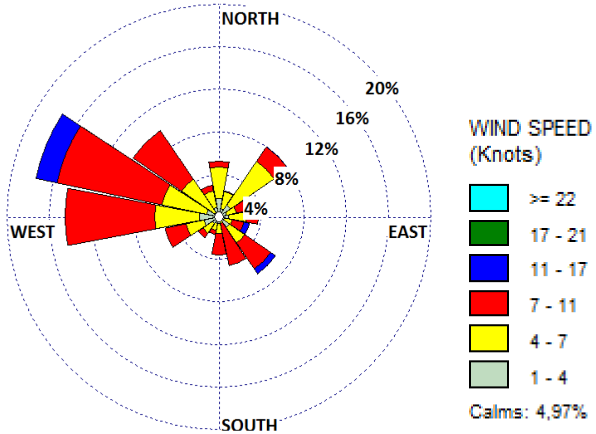
March (Baucau Meteorological Station)



January (www.weblakes.com)

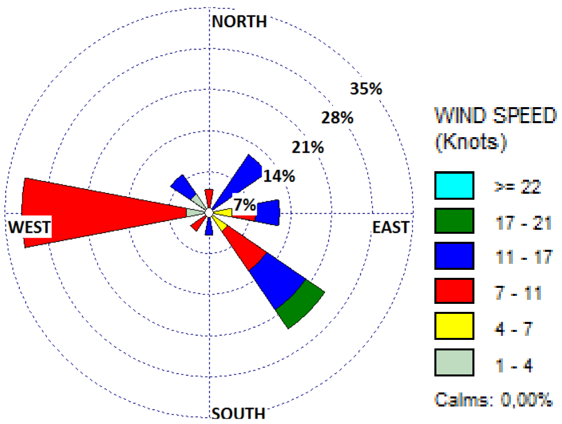


February (www.weblakes.com)

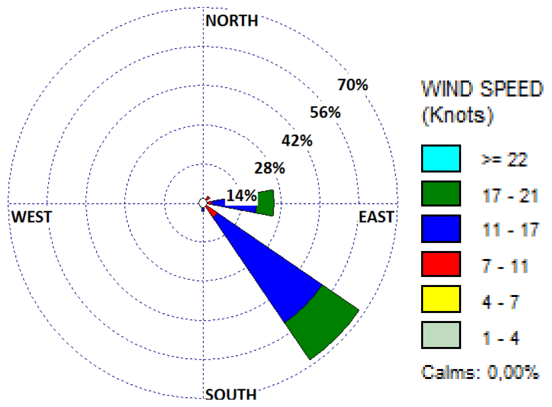


March (www.weblakes.com)

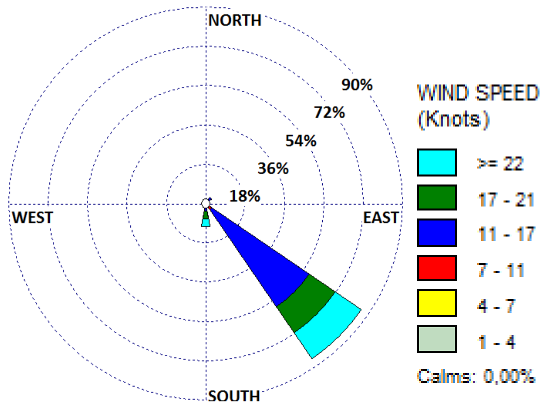
Figure 3.6 Monthly Windrose for Baucau Area from January to March 2014



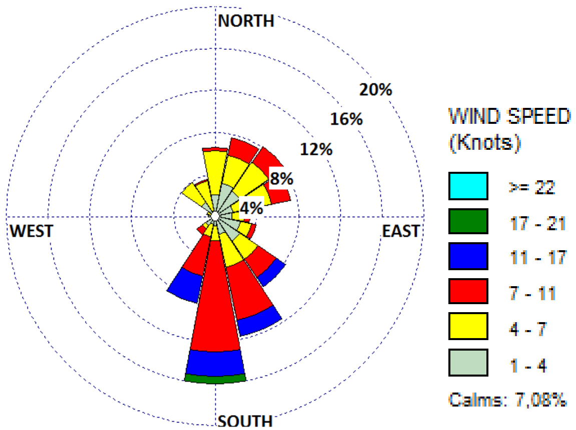
April (Baucau Meteorological Station)



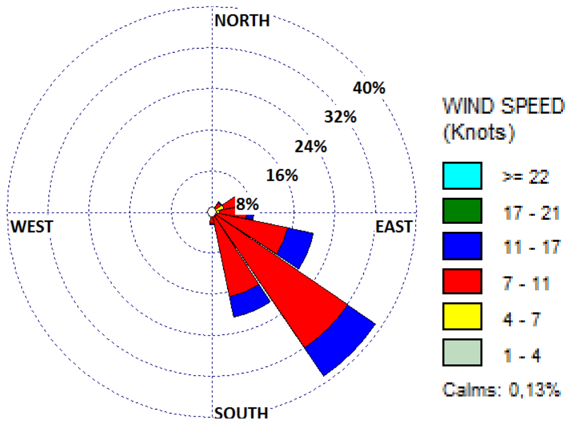
May (Baucau Meteorological Station)



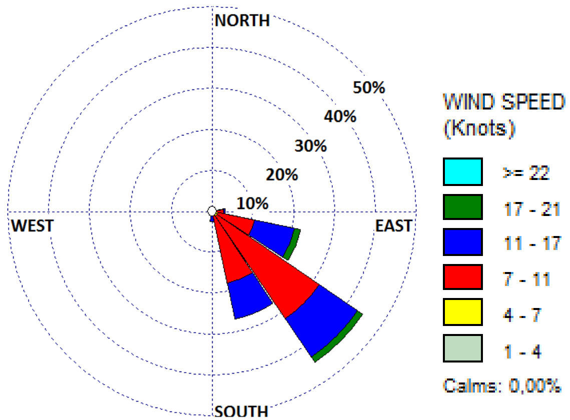
June (Baucau Meteorological Station)



April (www.weblakes.com)

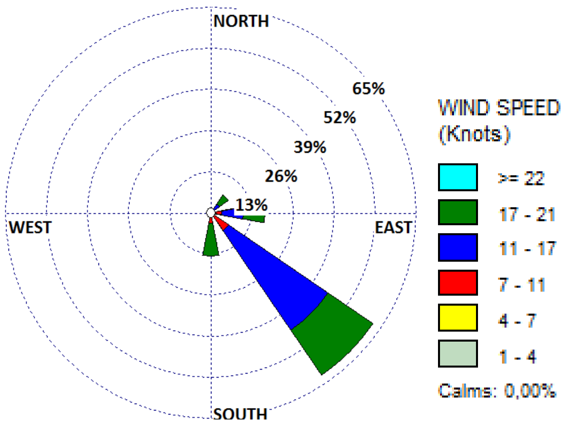


May(www.weblakes.com)

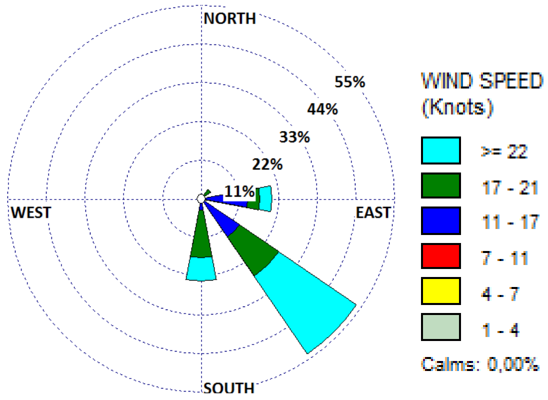


June(www.weblakes.com)

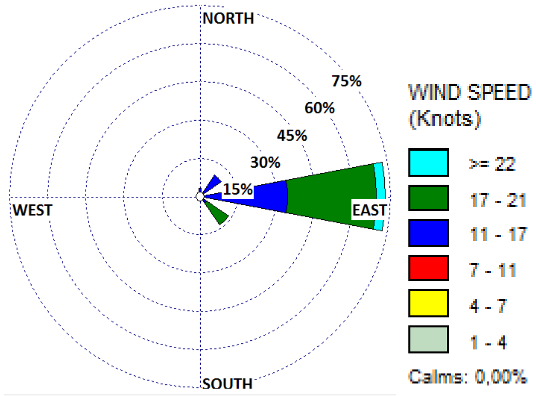
Figure 3.7 Monthly Windrose for Baucau Area from April to June 2014



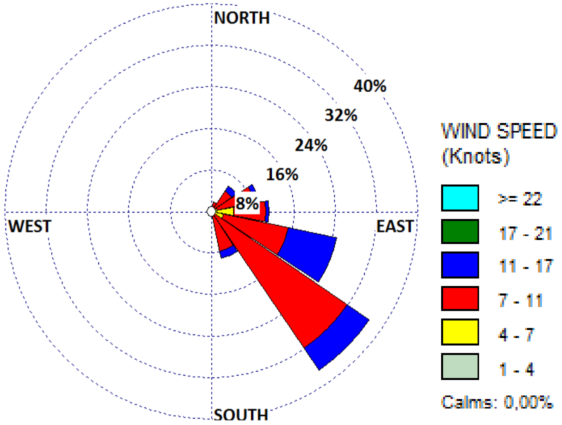
July (Baucau Meteorological Station)



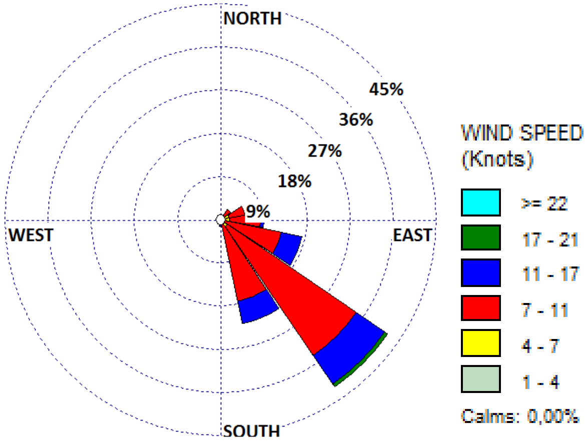
August (Baucau Meteorological Station)



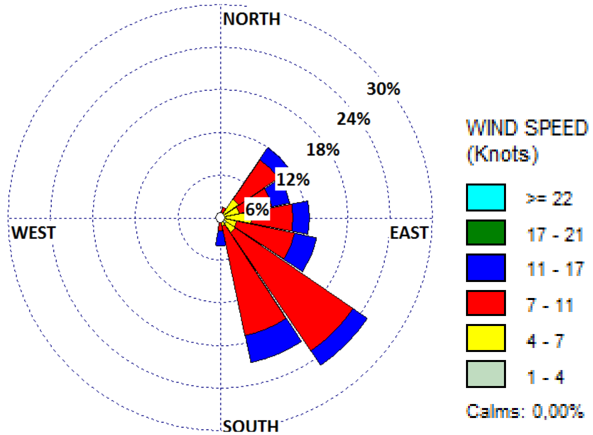
September (Baucau Meteorological Station)



July (www.weblakes.com)

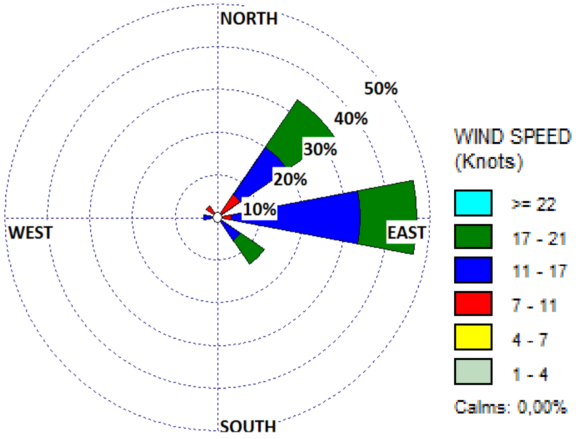


August (www.weblakes.com)

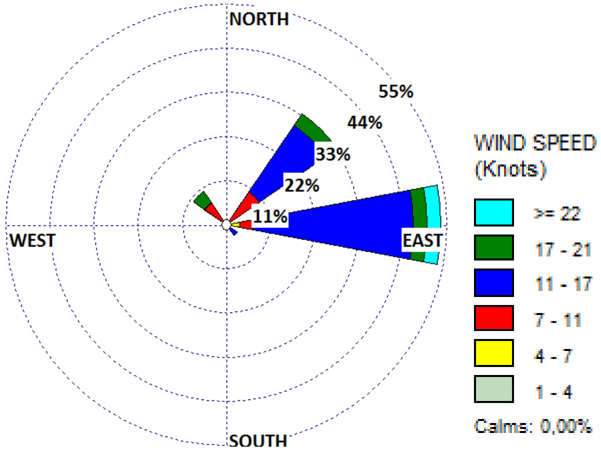


September (www.weblakes.com)

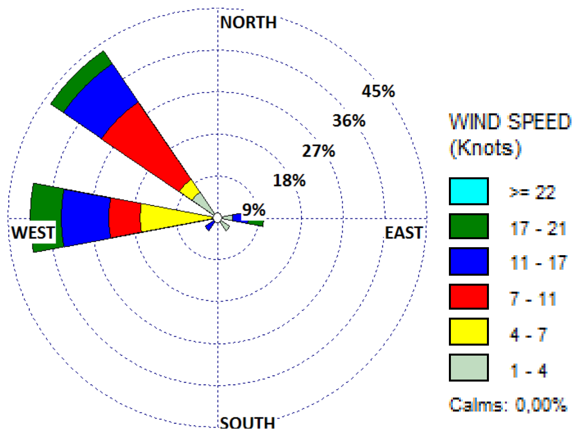
Figure 3.8 Monthly Windrose for Baucau Area from July to September 2014



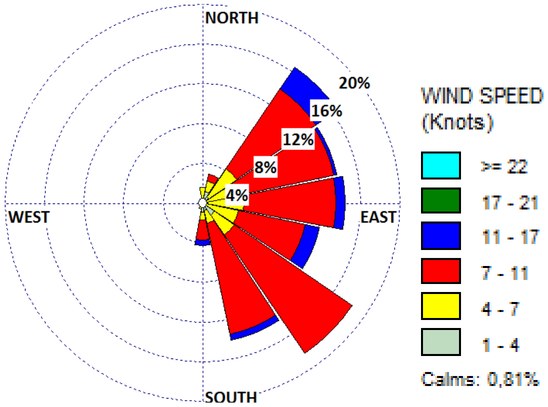
October (Baucau Meteorological Station)



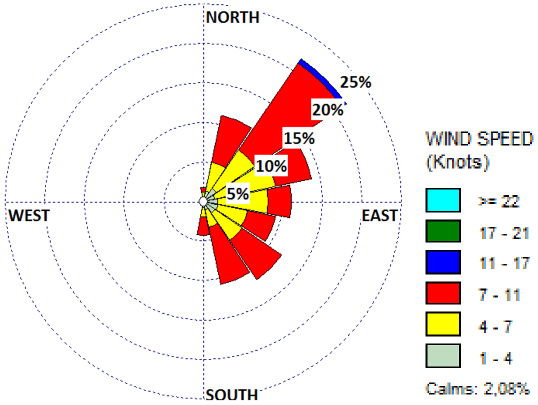
November (Baucau Meteorological Station)



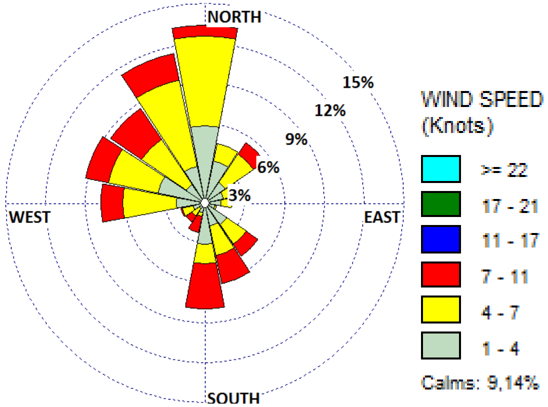
December (Baucau Meteorological Station)



October (www.weblakes.com)



November (www.weblakes.com)



December (www.weblakes.com)

Figure 3.9 Monthly Windrose for Baucau Area from October to December 2014

3.2 Air Quality Baseline

To analyse the baseline conditions within the study area, site visits and data collection exercise was carried out between 21st and 30th of May 2015 in order to:

- Assess the ambient air quality with the project and surrounding areas
- Identify the existing Air Sensitive Receptors within the study area ; and
- Establish the existing air emission sources (*i.e.* impact sources) in the vicinity of the study area that might have potential (*i.e.* incremental) impact(s) on the general air quality

Seven locations as shown in **Table 3.1, Figure 3.10** until **Figure 3.24** had been chosen to represent the air quality baseline around the project area. The site selection was carried out based on the followings considerations:

- Locations which will undergo the impact of dispersed air pollutant emitted from the cement plant activities.
- Locations which are occupied by local people.

Table 3.1 Sampling Location for Collecting Primary Air Quality Data (Representative Location of Sensitive Receptors)

No.	Location	Zone	Easting	Northing	Description	Note
1.	AQ-1 Bahu	52L	216789	9063590	Settlement Area	East – south east of cement plant activities
2.	AQ-2 Check Point Triloca	52L	210449	9060528	Settlement Area	South of cement plant activities
3.	AQ-3 Aldeia Parlementu	52L	212219	9065491	School Area	East of cement plant and north east of limestone mine
4.	AQ-4 Aldeia Osso-ua	52L	209130	9065049	Settlement Area	Close the Plant Area
5.	AQ-5 Jetty Plan	52L	207556	9065473	Jetty Area	Within the Jetty Area
6.	AQ-6 Wailacama	52L	204204	9060553	Settlement Area	North east of clay quarry
7.	AQ-7 Bucoli	52L	207767	9060792	Settlement Area	South of mine and plant, North east of clay mine

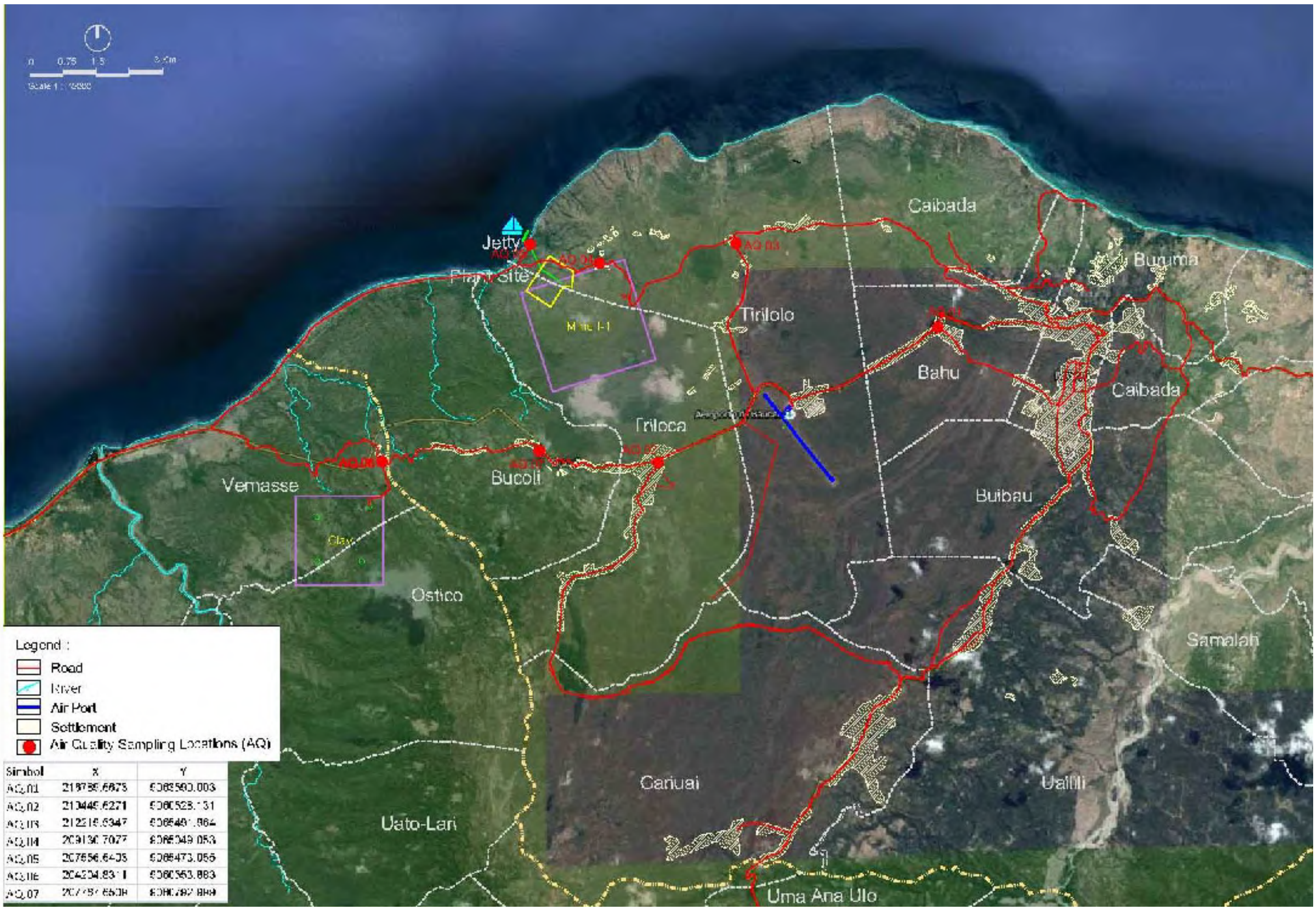


Figure 3.10 Location of Air Quality Measurement

The results of air quality measurement in these locations will be considered as the background concentration of measured parameters, i.e. the concentration before the project begins. Several activities either during construction phase or during operation phase shall contribute to the increase of emission of air pollutants to the ambient air surrounding the project area.

Emission of particulates during construction phase mainly originate from the works related to site preparation, material stock piling, and vehicle movement on unpaved or paved road. Pollutant in the form of gases mainly emitted as the result of fuel combustion from operation of heavy equipment. During the operation phase, emissions from the kiln are a combination of combustion and process emissions but the emissions of the main pollutants - NO_x, sulphur oxides (SO_x), carbon monoxide (CO), non-methane volatile organic compounds (NMVOC), as well as heavy metals and persistent organic pollutants (POPs) are assumed to originate mainly from the combustion of the fuel.

Figure 3.11 AQ-1, Location of Air Quality Measurement in Bahu

Figure 3.12 AQ-1, Location of Air Quality Measurement in Bahu (Another Point of View)

Figure 3.13 AQ-2, Location of Air Quality Measurement in Check Point Triloca

Figure 3.14 AQ-2, Location of Air Quality Measurement in Check Point Triloca
(Another Point of View)

Figure 3.15 AQ-3 Location of Air Quality Measurement in Aldeia Parlementu

Figure 3.16 AQ-3 Location of Air Quality Measurement in Aldeia Parlementu (Another Point of View)

Figure 3.17 AQ-4 Location of Air Quality Measurement in Aldeia Osso-ua

Figure 3.18 AQ-4 Location of Air Quality Measurement in Aldeia Osso-ua
(Another Point of View)

Figure 3.19 AQ-5 Location of Air Quality Measurement in Jetty Plan

Figure 3.20 AQ-5 Location of Air Quality Measurement in Jetty Plan
(Another Point of View)

Figure 3.21 AQ-6 Location of Air Quality Measurement in Wailacama

Figure 3.22 AQ-6 Location of Air Quality Measurement in Wailacama (Another Point of View)

Figure 3.23 AQ-6 Location of Air Quality Measurement in Bucoli

Figure 3.24 AQ-6 Location of Air Quality Measurement in Bucoli (Another Point of View)

PM_{10} and $PM_{2.5}$

Particulate is the term of dispersed air pollutant in the solid or liquid form in the atmosphere. PM_{10} is the dispersed solid particulate with a diameter of 10 micrometers or less, while $PM_{2.5}$ µm has diameter of 2.5 µm or less. These particulates are likely responsible for adverse health effects because of their ability to reach the lower regions of the respiratory tract.

Results of measurement of 24 hour ambient concentrations of PM_{10} and $PM_{2.5}$ in seven locations (AQ1 until AQ7) are shown in **Figure 3.25 and Figure 3.26**. All measured PM_{10} concentrations are below the standard (150 µg/m^3) according to US EPA (2013) and WHO (2005). Similarly, 24 hour PM ambient concentrations of $PM_{2.5}$ are also below the standard (75 µg/m^3) according to WHO (2005), and the standard (35 75 µg/m^3) according to US EPA (2012).

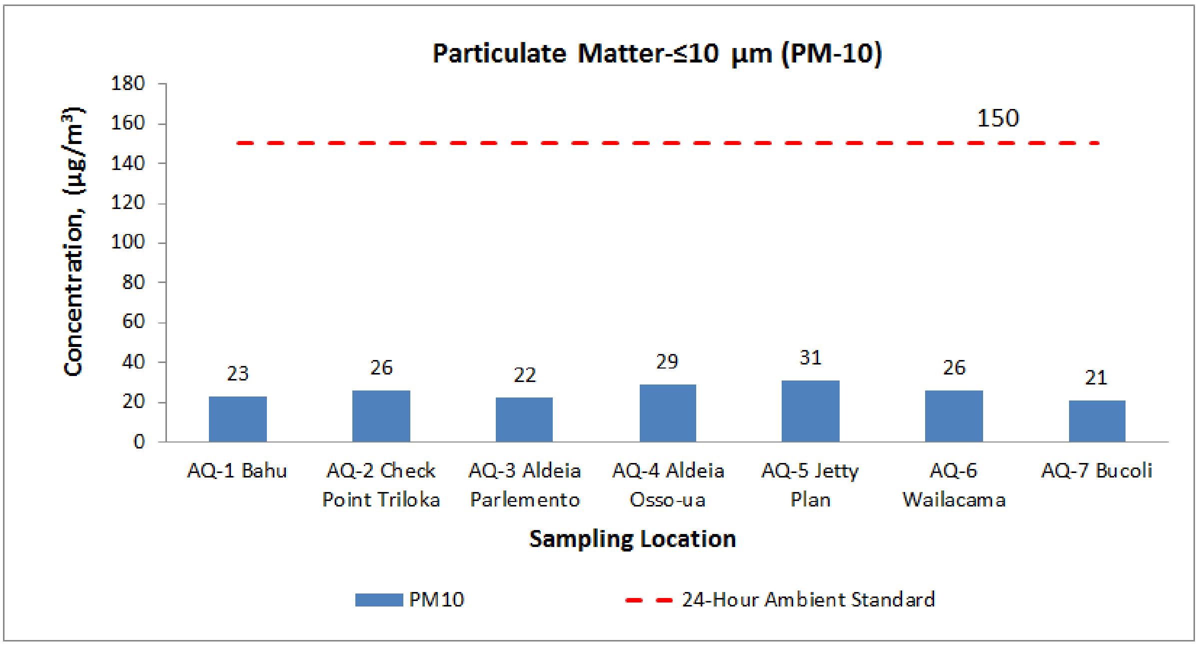


Figure 3.25 24 Hour-Ambient Concentration of PM_{10}

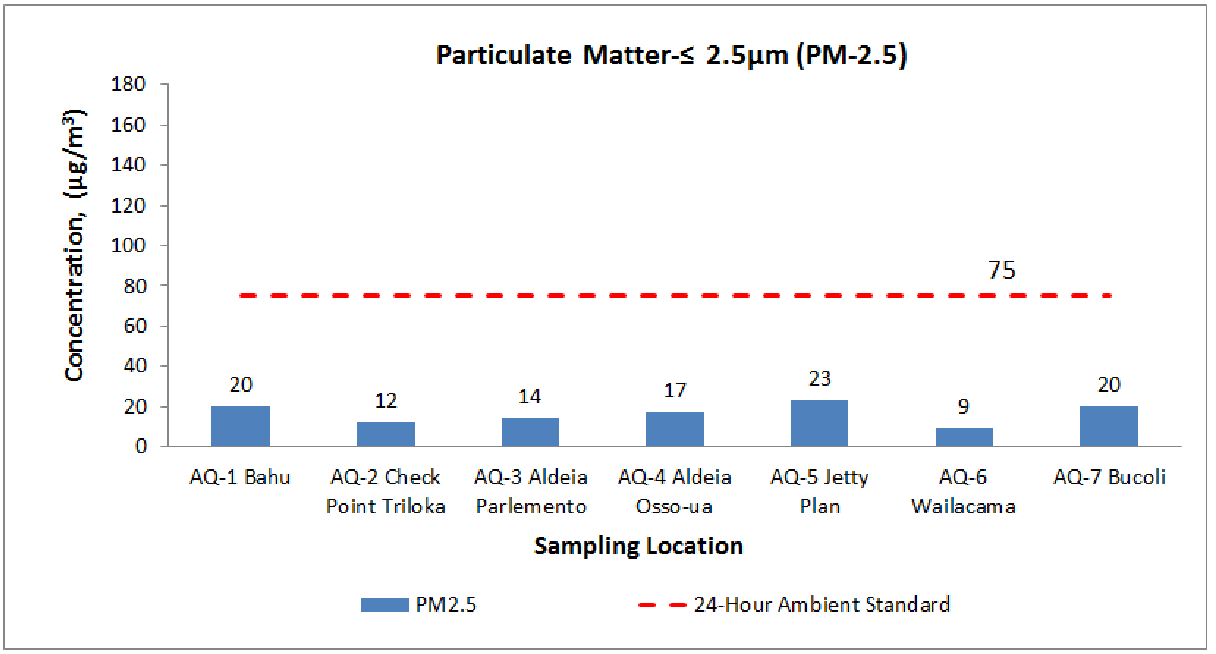


Figure 3.26 24 Hour-Ambient Concentration of $PM_{2.5}$

During the construction and operation phase of cement plant, there shall be an increase of particulate emission to the ambient air. Sources of particulate at cement plants include (1) quarrying and crushing, (2) raw material storage, (3) grinding and blending (in the dry process only), (4) clinker production, (5) finish grinding, and (6) packaging and loading. The largest emission source of particulate within cement plants is the pyro-processing system that includes the kiln and clinker cooler exhaust stacks. Often, dust from the kiln is collected and recycled into the kiln, thereby producing clinker from the dust. However, if the alkali content of the raw materials is too high, some or all of the dust is discarded or leached before being returned to the kiln. In many instances, the maximum allowable cement alkali content of 0.6 percent (calculated as sodium oxide) restricts the amount of dust that can be recycled. Bypass systems sometimes have a separate exhaust stack. Additional sources of PM are raw material storage piles, conveyors, storage silos, and unloading facilities. The magnitude of emission will be strongly influenced by the control during each stage of operation. Dust suppression facilities and actions such as road watering, stockpile covering, de-dusting mechanism using fabric filter or electrostatic precipitator, barrier installation, etc. will have significant influence in reducing the particulate emissions.

After being emitted to the atmosphere, PM_{10} and $PM_{2.5}$ shall undergo several processes such as dispersion and chemical or physical transformations in the atmosphere which are strongly influenced by the meteorology. Those particles may finally be removed by deposition from the atmosphere to the earth's surface. Deposition caused by precipitation is called wet deposition; and deposition processes which are not influenced by precipitation are summarized as dry deposition. A third kind of deposition, through which water droplets are deposited by interception of fog, mist, or clouds, is referred to as occult deposition. Since this process plays only a significant role in areas with frequent orographic cloud cover (Dollard et al. 1983), it can be neglected in most urban areas.

Wet deposition comprises processes in which particles are cooperated into droplets and subsequently transferred to the earth's surface. Particles might either serve as condensation nuclei for atmospheric water and be incorporated into the formed droplet or collide with an existing droplet. If these processes occur within a cloud, they are called in-cloud scavenging or rainout. If they take place below the cloud, they are named below-cloud scavenging or washout (Seinfeld and Pandis, 2006).

Wet deposition is a very effective way to remove particles from the atmosphere. In Baucau, wet deposition may occur during wet season which lasts from December to May.

The term dry deposition encompasses several mechanisms like turbulent diffusion, sedimentation, Brownian diffusion, interception, inertial forces, electrical migration, and etc. Deposition rates are governed by many factors, including meteorological variables such as wind velocity or relative humidity, properties of the particles (e.g., particle size and shape), and variables of the surface on which the particles are deposited. This dry deposition may occur mainly during dry season in Baucau which lasts from June to November. When considering particle dry deposition, a special focus is often laid on urban vegetation, since it provides a distinct larger surface area compared to the ground on which it stands. An optimized planting of vegetation along roads can also reduce re-suspension of particles by motorized traffic.

Carbon Monoxide

Carbon monoxide is a colourless, odourless, tasteless, and very stable gas which has lifetime between 2 until 4 months in the atmosphere. Naturally, CO is the second gas after CO_2 as the gas which has the highest concentration in the lower atmosphere (troposphere). Its natural sources originate from volcano and natural forest fire; cause the concentration around 0.2 ppm (229 µg/m^3). Anthropogenic sources of CO mostly come from the incomplete combustion of fossil fuel or combustion of fuel in motorized vehicles.

Results of CO measurements in seven locations are shown in **Figure 3.27**. One hour concentrations of CO in seven locations, were measured between 218 to 481 µg/Nm^3 far below the 1 hour standard (30.000 µg/m^3) according to WHO (2010). These concentrations are closer to the concentration of natural CO, which indicates that the current anthropogenic activities only slightly increase the ambient concentration of CO.

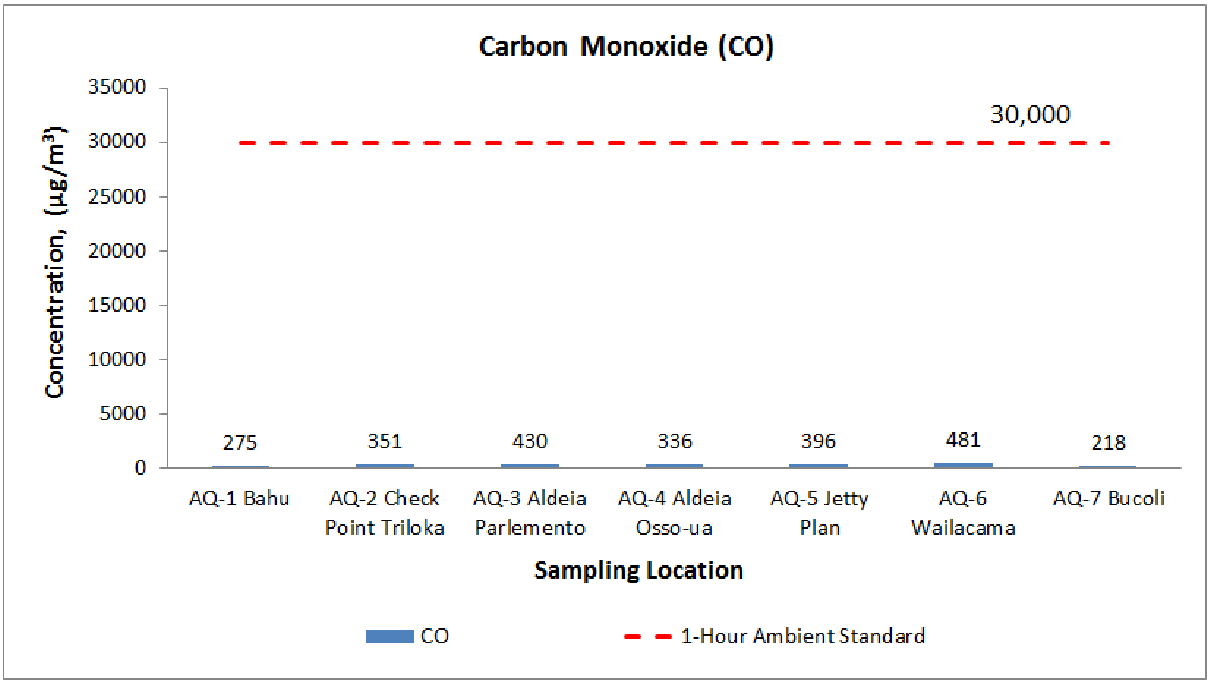


Figure 3.27 One Hour Ambient Concentration of CO

Emissions CO can occur in the primary steps of the kiln process (preheater, precalciner), when impurities (such as organic matter) that are present in the raw materials are volatized as the raw mix is heated. Elevated CO levels occur in cement kilns or a number of reasons. Calcinations, which is critical to the cement production process, results in CO by product, as does the decomposition of carbon dioxide due to extremely high moisture and metallic catalyst. Finally, partial oxidation of hydrocarbons present in raw materials may also produce CO.

Nitrogen Dioxides

Nitrogen dioxide (NO_2) and nitrogen monoxide (NO) are compound containing nitrogen in the atmosphere, and become very important indicator of air pollution. Naturally, NO_x can be formed in the atmosphere through lightning, oxidation of NO with the help of ozone, as well as activities in farming area. Anthropogenic sources originate from the process of combustion of fuel containing nitrogen (fuel NO_x) or from combustion condition at high temperature where reaction between N_2 and O_2 might occur (thermal NO_x).

One hour nitrogen dioxide concentrations in Baucau area which were measured in seven locations are still below the standard (200 µg/m^3) according to WO (2005) and European Union as shown in **Figure 3.28.** The measured concentration ranged between 7 to 28 µg/m^3.

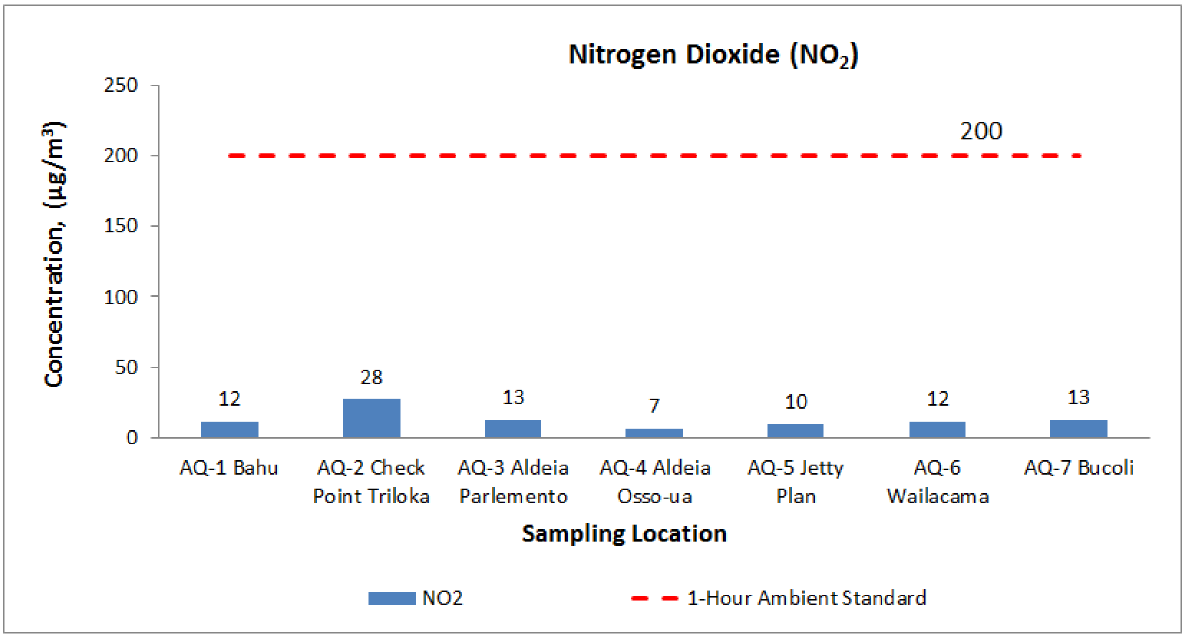


Figure 3.28 One Hour Ambient Concentration of NO_2

As it was illustrated before, NO_x are formed in the combustion process either by oxidation of the nitrogen in the combustion air (thermal NO_x), or by oxidation of the nitrogen compounds in the fuel (fuel NOx). Thermal NO_x is formed at temperatures above 1200˚C. Due to the very high temperatures in the cement kiln thermal NO_x dominate the composition of produced NO_x. Nitrogen monoxide accounts for about 95 % and nitrogen dioxide for about 5 %.

Sulphur Dioxide

Sulphur dioxide is a non-flammable gas, not explosive, colourless and can cause a sensational taste at concentration of 0.3 ppm (784 µg/Nm^3) until 1 ppm (2,612 µg/Nm^3). Sulphur dioxide can easily react with other component to form a dangerous compound such as sulphite acid, sulphate acid, and other sulphate particles. Natural resources of SO_2 originate from volcano, ocean, decomposition processes, and natural forest fire. 24 hour average concentration of SO_2 originates from natural sources is about 10 µg/Nm^3 (EMEP-MSC, 1995). Sulphur dioxide from anthropogenic sources is emitted from industrial activities which utilize coal as energy source, smelting process, sulphate acid production, pulp and paper, and incineration of waste containing sulphur.

Results of SO_2 measurements (**Figure 3.29**) in seven location show that SO_2 concentration are far below the standard (196 µg/m^3 and) according to WHO (2005). The measured concentrations range between <8.5 µg/m^3 to 18 µg/m^3, which are around the level of natural concentration.

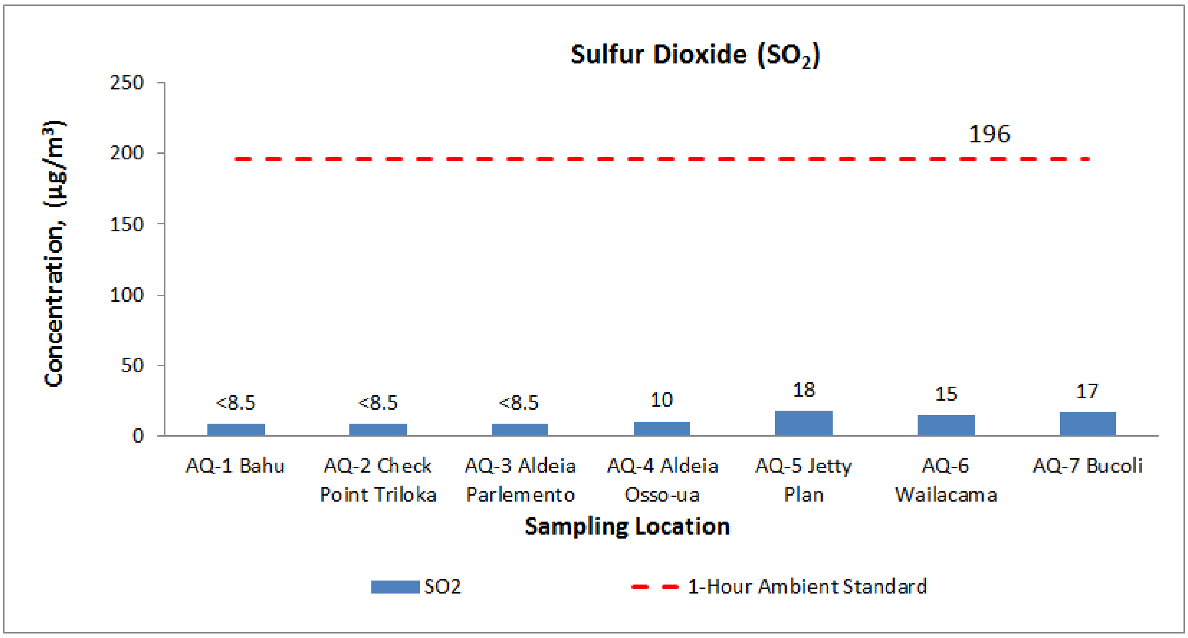


Figure 3.29 One Hour Ambient Concentration of Sulphur Dioxide (SO_2)

SO_2 emissions from cement plants are primarily determined by the content of volatile sulphur in the raw materials. This sulphur is emitted as SO_2 from the low temperature end of the kiln system. Sulphur present as sulphate in the raw materials is only partly decomposed at high temperatures and almost completely discharged from the kiln system with the clinker. Sulphur introduced into the kiln with the fuels is oxidized to SO_2 and will not lead to significant SO_2 emissions as SO_2 formed at the hot end of the kiln system reacts with the reactive, fine raw materials in the sintering zone, the pre-calciner and the hot part of the preheater.

Hydrocarbon

Hydrocarbon is the organic compound consists of carbon and hydrogen. The term of hydrocarbon can also be used for the functionalized organic compound (VOC) consists of atoms such as oxygen, hydrogen, halogen (chlorine, bromine, and Iodine), nitrogen, and phosphor. Hydrogen might exist in the atmosphere in two forms, depends on its volatility and its vapor pressure. If exist in the form of semi volatile compound (SVOC), the hydrocarbon are freely move in the atmosphere. If the hydrocarbon has a low vapor pressure, it can have a semi volatile condition. Hydrocarbon can also be differentiated as methane hydrocarbon (MHC) and non-methane hydrocarbon (NMHC).

Hydrocarbon as trace gases in the atmosphere has a very low concentration. Methane has the highest concentration, around 1.7 ppm (1,110 µg/m^3). Other types of hydrocarbon are measured in the very low concentration, e.g., isoprene (C_5H_8) is 0.6 – 2.5 ppb (2-7 µg/Nm^3) and terpene ($C_{10}H_{16}$) is 0,03 – 2 ppb (0,2 – 11 µg/Nm^3).

Results of measurement shows concentration of 3 hour ambient concentration of NMHC in seven locations are still below the standard (160 µg/m^3) according to US EPA. All measured concentration are below the detection of the method, i.e. less than 1 µg/m^3 as shown in **Figure 3.30**.

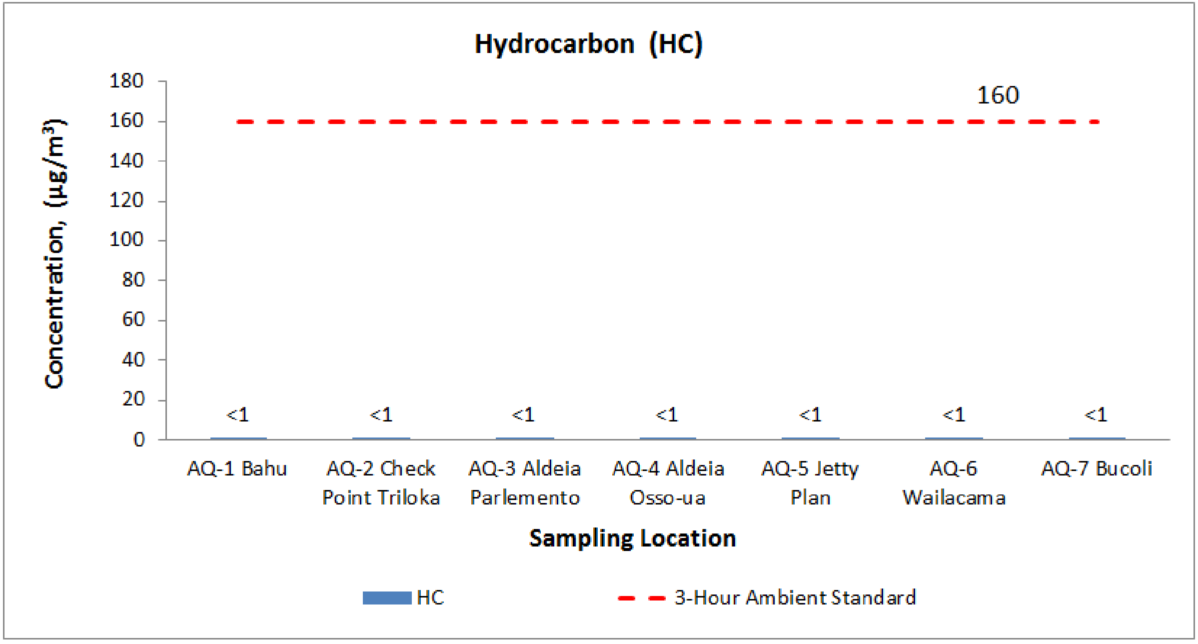


Figure 3.30 Three Hour Ambient Concentration of Hydrocarbon

Ozon (O_3)

Natural ozone in lower atmosphere (troposphere) has concentration of 20 ppb (40 µg/m^3). Additional ozone concentration might come from the chemistry reaction in troposphere and movement of ozone form stratosphere to troposphere. Ozone formation as the results of anthropogenic activities occur when hydrocarbon react with nitrogen oxide in the present of sunlight. Mixing between reactant and product related to hydrocarbon, nitrogen oxide, and sunlight is called as photochemical smog.

Results of ozone measurement in seven locations show the concentration far below the standard (235 µg/Nm^3) according to US EPA 1997 (see **Figure 3.31**). The measured ozone value is between < 2.5 µg/m^3 and 19 µg/m^3. The observation of ozone concentration is an important part of air quality monitoring, because ozone is a secondary pollutants which is not directly emitted from the source, but formed in the atmosphere due to photochemical reactions of primary air pollutants (NO_2 and hydrocarbon) in the present of sunlight.

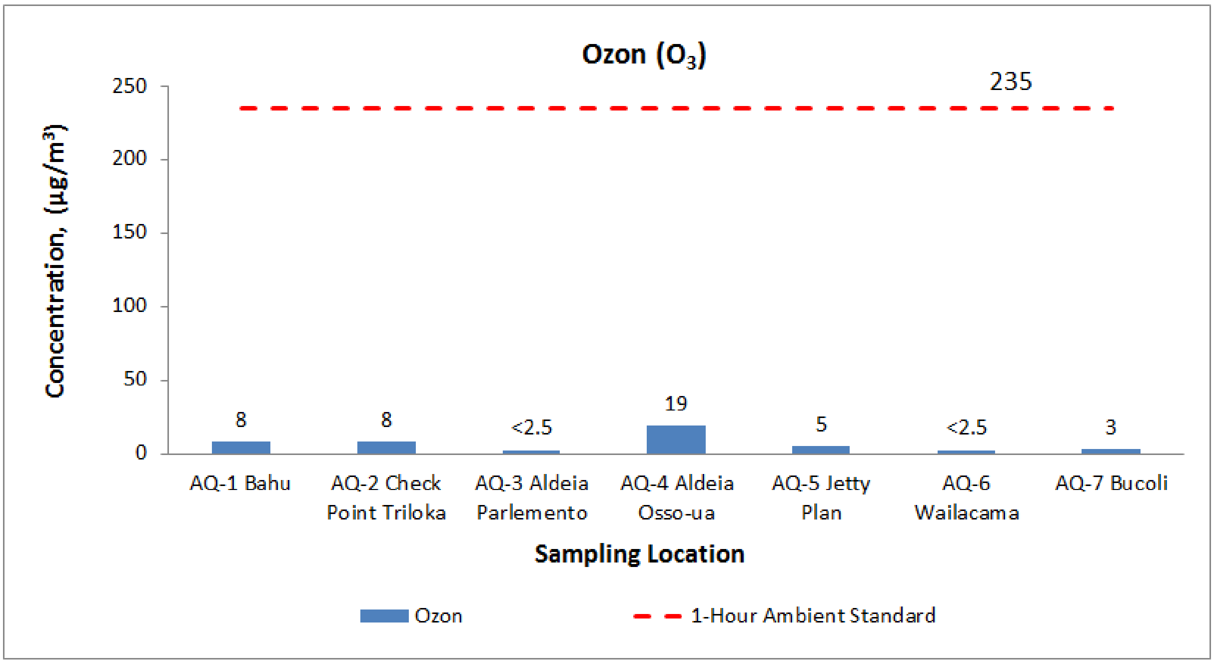


Figure 3.31 One Hour Ambient Concentration of Ozone

4. IMPACT ASSESSMENT

Impact assessment of cement TL activities was carried out quantitatively by using modelling tools, both during construction and operation phase. The impact assessment divided into two major parts, i.e.; the emission inventory and prediction of future ambient air quality. Emission rates from inventory calculation become the input for prediction of future ambient air quality combine with other supporting data such as Baucau meteorological data and topographical data. The results of prediction are presented in the form isopleth map to describe the dispersion of air pollutants over the project surrounding area and sensitive receptors.

4.1 Emission Inventory

Emissions during the construction of the project can be associated with site preparation and construction of a particular facility itself. Dust emissions often vary substantially from day to day, depending on the level of activity, the specific operations, and the prevailing meteorological conditions. The quantity of dust emissions from constructions and operations are proportional to the area of land being worked and to the level of construction activity. By analogy to the parameter dependence observed for other similar fugitive dust sources, one can expect emissions from heavy construction and operations to be correlated with the silt content of the soil (that is, particles smaller than 75 micrometers [μm] in diameter), the speed and weight of the average vehicle, as well as the soil moisture content. Detail calculations of emission rates from particulate (dust) and gas generating activities in cement plant and jetty area, limestone mine, and clay mine are described in **Table 4.1** until **Table 4.5**.

Emissions during the operation phase can be classified into four major sources which are calculated according to area specific activities:

- Particulates and gases from cement plant operation

  There are five main point sources (kiln house stack, cooler electrostatic precipitation stack, cement mill bag house stack, coal mill bag house stack, and thermal power plant stack) which continuously emit air pollutants associated with the operation stage of the cement plant as described in **Table 4.6**.

- Particulate and gases from limestone mine and clay mine operation

  Emissions of particulates occur from a number of operations in material quarrying and processing. Activities such as bulldozing, truck loading/unloading, blasting, drilling, active storage pile (where wind erosion might occur) and vehicle movements are considered to be the main source of particulate generation. Other particulate generation also comes from the operation of main and ancillary equipment during the mine operation. The combustion of fuels during the operation of this equipment may also release gases to the ambient air. Detail calculations for the emission rates of air pollutants are described in **Table 4.7** until **Table 4.10** for limestone mine operation and **Table 4.11** until **Table 4.13** for clay mine operation.

- Particulate and gases from clay hauling from clay mine to cement plant

  Clay hauling from clay mine to cement plant has a long route on a paved road, passes several villages start from Bucoli – Triloca – Tirilolo – Laelesu, Parlemento, Osso-ua, until cement plant. Particulate emissions occur whenever vehicles travel over a paved surface such as a road. Particulate emissions from paved roads are due to direct emissions from vehicles in the form of exhaust, brake wear and tire wear emissions and re-suspension of loose material on the road surface. In general terms, re-suspended particulate emissions from paved roads originate from, and result in the depletion of the loose material present on the surface (i.e., the surface loading).

Detail calculation for particulate and gases from clay hauling are shown in **Table 4.14** until **Table 4.16**.

Construction Phase

- *Particulates from site preparations*

Table 4.1 Activity Data of Site Preparation

No	Dust Generating Activities	Activity Supporting Data													
		Number of equipment			Silt content	Moisture Content	Operating hours	Mean Vehicle Speed	Wind Speed	Material	Active Storage Area	Vehicle km travel	Average Weight of the Vehicles	Mean number of wheels	number of days with at least 0.254 mm of precipitation per year
		Cement Plant and Jetty	Limestone Mine	Clay Mine											
					s	M		S	U	Mat	A	VKT	W	w	p
					%	%	hours/day	VKT		Mg/day	Ha	km/day	ton		days
1	Bulldozing (top soil)	1	1	1	6.2	10	5.5								
						10			8	10					
3	Active storage pile (emission due to wind erosion and maintenance										2				
4	Vehicle movement	21	7	4	6.2			25				40	15	8	130

Table 4.2 Emission Rate Calculation for Site Preparation

No	Dust Generating Activities	Emission Factor				Emission Rate					
						Cement Plant Area		Limestone Mine		Clay Mine	
		PM_{10}	$PM_{2.5}$	Unit	Source	PM_{10}	$PM_{2.5}$	PM_{10}	$PM_{2.5}$	PM_{10}	$PM_{2.5}$
		EF				E					
						g/s					
1	Bulldozing (top soil)	$0.75 \frac{18.6 (s)^{1.5}}{(M)^{1.4}}$	$0.022 \frac{78.4 (s)^{1.2}}{(M)^{1.3}}$	Kg/hour	AP.42 Sec.13.2, Table 13.2.3	E =R*1000*(EF*OH)/(24*3600)					
		9.034515535	1.824691436			6.E-01	1.E-01	6.E-01	1.E-01	6.E-01	1.E-01
2	Loading and unloading excavated material using trucks	$k * 0.0016 * \frac{(\frac{U}{2.2})^{1.3}}{(\frac{M}{2})^{1.4}}$ k=0.35 for PM10,& 0.053 for PM 2.5		Kg/Mg	Ap.42 Sec. 13.2.4	E =2*1000*(EF*Mat)/(24*3600)					
		0.000315	0.000048			7.E-05	1.E-05	7.E-05	1.E-05	7.E-05	1.E-05
3	Active storage pile (emission due to wind erosion and maintenance	*0.85 for TSP, multiplication factor for PM10: 0.75, and PM2.5: 0.105		Mg/hectare/ year	Ap.42 Sec.11.9, Table 11.9.2	E =1000*(EF*A)/(365*24*3600)					
		0.6375	0.08925			4.E-05	6.E-06	4.E-05	6.E-06	4.E-05	6.E-06
4	Vehicle movement	$E = k\, 5.9 \left(\frac{s}{12}\right)\left(\frac{S}{30}\right)\left(\frac{W}{3}\right)^{0.7}\left(\frac{w}{4}\right)^{0.5}\left(\frac{365-p}{365}\right)$ K = 0.36 for PM_{10}, and 0.095 for $PM_{2.5}$		g/VKT		E = (R*VKT*EF)/(24*3600)					
		722.1526	190.5681			2.E-02	5.E-03	6.E-03	2.E-03	4.E-03	1.E-03
	Total					6.E-01	1.E-01	6.E-01	1.E-01	6.E-01	1.E-01

Table 4.3 Main Equipment Activities for Site Preparation

No	Equipment	Cement Plant and Jetty	Limestone Mine	Clay Mine	Capacity	Operating Hours	PM_{10}	$PM_{2.5}$	CO	NO_x	SO_2
		Activities					Emission Factor				
					P	OH					
					bhp	hours/day					
1	Water truck/fuel truck, MHDT	7	2	2		8	1.88	0.72	4.62	7.31	0.01
2	Crane	7			173	8	0.26	0.239	3.41	5.1	0.006
3	Low & Flat bed trailer, HHDT	7	2	1		8	2.3	0.72	10.14	7.31	0.03
4	Fork lift	3			173	8	0.249	0.229	3.353	4.32	0.006
5	Welding generators	5			49	8	0.525	0.483	6.028	5.549	0.007
6	Excavator	3	2	1	173	8	0.259	0.239	3.377	4.523	0.006
7	Bulldozer / Ripper	3	1	1	493	8	0.14	0.129	3.053	4.7	0.006
8	Dump Truck, HHDT	7	3	2		8	2.3	0.72	10.14	7.31	0.03
9	Motor Grader		1		173	8	0.26	0.239	3.369	5.1	0.006
10	Wheel Loader	5			247	8	0.109	0.1	1.194	2.8	0.006
11	Power generators	2	1	1	226	8	0.13	0.12	1.27	3.87	0.01

Table 4.4 Emission Rate Calculation for Main Equipment Activities during Construction Phase

No	Equipment	Emission														
		Cement Plant and Jetty					Limestone Mine					Clay Mine				
		PM_{10}	$PM_{2.5}$	CO	NO_x	SO_2	PM_{10}	$PM_{2.5}$	CO	NO_x	SO_2	PM_{10}	$PM_{2.5}$	CO	NO_x	SO_2
		g/s														
1	Water truck/fuel truck, MHDT	E = (R*EF*OH)/(24*3600)														
		1.2E-03	4.7E-04	3.0E-03	4.7E-03	6.5E-06	3.5E-04	1.3E-04	8.6E-04	1.4E-03	1.9E-06	3.5E-04	1.3E-04	8.6E-04	1.4E-03	1.9E-06
2	Crane	E = (R*EF*P*OH)/(24*3600)														
		2.9E-02	2.7E-02	3.8E-01	5.7E-01	6.7E-04										
3	Low & Flat bed trailer, HHDT	E = (R*EF*OH)/(24*3600)														
		1.5E-03	4.7E-04	6.6E-03	4.7E-03	1.9E-05	4.3E-04	1.3E-04	1.9E-03	1.4E-03	5.6E-06	2.1E-04	6.7E-05	9.4E-04	6.8E-04	2.8E-06
		E = (R*EF*P*OH)/(24*3600)														
4	Fork lift	1.2E-02	1.1E-02	1.6E-01	2.1E-01	2.9E-04										
5	Welding generators	1.2E-02	1.1E-02	1.4E-01	1.3E-01	1.6E-04										
6	Excavator	1.2E-02	1.1E-02	1.6E-01	2.2E-01	2.9E-04	8.3E-03	7.6E-03	1.1E-01	1.4E-01	1.9E-04	4.1E-03	3.8E-03	5.4E-02	7.2E-02	9.6E-05
7	Bulldozer / Ripper	1.9E-02	1.8E-02	4.2E-01	6.4E-01	8.2E-04	6.4E-03	5.9E-03	1.4E-01	2.1E-01	2.7E-04	6.4E-03	5.9E-03	1.4E-01	2.1E-01	2.7E-04
8	Dump Truck, HHDT	E = (R*EF*OH)/(24*3600)														
		1.5E-03	4.7E-04	6.6E-03	4.7E-03	1.9E-05	6.4E-04	2.0E-04	2.8E-03	2.0E-03	8.3E-06	4.3E-04	1.3E-04	1.9E-03	1.4E-03	5.6E-06
		E = (R*EF*P*OH)/(24*3600)														
9	Motor Grader	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	4.2E-03	3.8E-03	5.4E-02	8.1E-02	9.6E-05	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
10	Wheel Loader	1.2E-02	1.1E-02	1.4E-01	3.2E-01	6.8E-04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
11	Power generators	5.4E-03	5.0E-03	5.3E-02	1.6E-01	4.2E-04	2.7E-03	2.5E-03	2.7E-02	8.1E-02	2.1E-04	2.7E-03	2.5E-03	2.7E-02	8.1E-02	2.1E-04
	Total	1.1E-01	9.6E-02	1.5E+00	2.3E+00	3.4E-03	2.3E-02	2.0E-02	3.3E-01	5.3E-01	7.9E-04	1.4E-02	1.3E-02	2.2E-01	3.7E-01	5.9E-04

Table 4.5 Emission Rate from Construction Phase

No	Source	Cement Plant and Jetty Construction					Limestone Plan Construction					Clay Mine Construction				
		PM_{10}	$PM_{2.5}$	CO	NO_x	SO_2	PM_{10}	$PM_{2.5}$	CO	NO_x	SO_2	PM_{10}	$PM_{2.5}$	CO	NO_x	SO_2
		g/s/m²														
1	Site preparation	2.E-06	3.E-07				2.E-06	3.E-07				2.E-06	3.E-07			
2	Equipment activities during construction phase	3.0E-07	2.7E-07	4.2E-06	6.5E-06	9.6E-09	6.6E-08	5.8E-08		1.5E-06	2.2E-09	4.1E-08	3.6E-08	6.4E-07	1.1E-06	1.7E-09
	Total	2.0.E-06	6.E-07	4.E-06	6.E-06	1.E-08	1.7.E-06	3.9.E-07	9.5E-07	1.5E-06	2.2E-09	1.69.E-06	3.7.E-07	6.E-07	1.E-06	2.E-09

Note: Calculation was made based on an assumption concentrated area of the construction activities about 35 Ha

Operation Phase

- *Particulates and gases from cement plant operation*

Table 4.6 Emission from Cement Plant Operation - Main Point Sources

No.	Point Source	Stack Diameter	Stack Height	Gas Stack Temperature	Velocity	Output concentration				Cross Section Area	Gas Flowrate	Emission rate				
						PM_{10}	SO_2	NO_2	C0			PM_{10}	$PM_{2.5}$	SO_2	NO_2	CO
		D	H	T	v	C				A_{cross} = 0.25 □ D	Q = A_{cross}*v	E = (Q*C)/1000				
		m	m	Celsius	m/s	mg/Nm^3				m^2	m^3/s	g/s				
1	Kiln/Raw mill bag House stack	4	120	120	18	30	200	800	500	12.57	226.29	6.79	0.95	45.26	181.03	113.14
2	Cooler ESP stack	3.4	35	110	18	30				9.08	163.49	4.90	0.69			
3	Cement Mill bag House Stack	1.5	55	90	18	30				1.77	31.82	0.95	0.13			
4	Coal Mill Bag House Stack	2	65	77.5	18	30				3.14	56.57	1.70	0.24			
5	Thermal Power plant Stack	2.5	90	140	18	30	200	800	500	4.91	88.39	2.65	0.37	17.68	70.71	44.20

- *Particulate and gases from limestone mine operation*

Table 4.7 Activity Data of Limestone Mine Operation

No	Activity	Material	Activity Supporting Data															
			Pro-duction	Overbur-den & Inter-burden handling	Effective working hour per day	Mine Working Days	Number of blasting	Blasting area	Water Content	Opera-tion Hour	Silt Content	Vehicle Km Travel	average weight of the vehicles travelling the road	mean num-ber of wheels	Ave-rage wind speed	Mean vehicle speed	number of days with at least 0.254 mm of precipitation/year	Storage pile area
			C				B	A	M	OH	s	VKT	W	w	U	S	p	A
			ton/ year	ton/hour	hours/ day	days/ year	Blasting /year	m^2	%	hour/ year	%	VKT/year	tone		m/sec	km/hour		Hectare
1	Bulldozing	Overburden							10	1,650	6.2							
2	Truck Loading	Overburden	854,700	259	11.0	300												

No	Activity	Material	Activity Supporting Data: Pro-duction	Overbur-den & Inter-burden handling	Effective working hour per day	Mine Working Days	Number of blasting	Blasting area	Water Content	Opera-tion Hour	Silt Content	Vehicle Km Travel	average weight of the vehicles travelling the road	mean num-ber of wheels	Ave-rage wind speed	Mean vehicle speed	number of days with at least 0.254 mm of precipitation/year	Storage pile area
			C				B	A	M	OH	s	VKT	W	w	U	S	p	A
			ton/ year	ton/hour	hours/ day	days/ year	Blasting /year	m^2	%	hour/ year	%	VKT/year	tone		m/sec	km/hour		Hectare
3	Truck unloading	Overburden	854,700															
4	Blasting	Limestone / Overburden					20	9,498										
5	Drilling	Limestone	2,095,432															
6	Truck Loading	Limestone	2,095,432															
7	Truck unloading		2,095,432															
8	Active storage pile (wind erosion and maintenance)	Lime-stone or overburden																20.0
9	Dump truck movement	Unpaved road									6.20	59,400	3	8	8	25	15.5	

Table 4.8 Emission Rate Calculation for Limestone Mine Operation

No	Mining Activities: Activity	Material	Emission Factor Calculation: PM_{10}	$PM_{2.5}$	Unit	Emission Rate Calculation: PM_{10}	$PM_{2.5}$	PM_{10}	$PM_{2.5}$
			EF			E		E2	
						kg/year		g/s	
1	Bulldozing	Overburden	$((0,45*s^{1.5})/M^{1.4}))*0.75$	$((2,6*s^{1.2})/M^{1.3}))*0.105$	kg/jam	E = OH*EF		E2=(E*1000)/(365*24*3600)	
			0.2074	0.1222	kg/jam	342.25	201.61	1.1E-02	6.4E-03
2	Truck Loading	Overburden				C*EF			
			0.00036	0.0002	kg/Mg, kg/ton	307.69	170.94	9.8E-03	5.4E-03
			0.00036	0.0002	kg/t	307.69	170.94	9.8E-03	5.4E-03
4	Blasting	Limestone or Overburden	$(0,00022*A^{1.5})*0,52$	$(0,00022*A^{1.5})*0,03$	kg/blasting	B*EF			
			106	6	kg/blasting	2,118	122	6.7E-02	3.9E-03

No	Mining Activities		Emission Factor Calculation			Emission Rate Calculation			
	Activity	Material	PM_{10}	$PM_{2.5}$	Unit	PM_{10}	$PM_{2.5}$	PM_{10}	$PM_{2.5}$
			EF			E		E2	
						kg/year		g/s	
5	Drilling	Limestone				C*EF			
			0.00004		kg/ton	67		2.1E-03	3.0E-04
			0.000008		kg/ton	16.76		5.3E-04	7.4E-05
			0.000008		kg/ton	13		4.3E-04	6.0E-05
8	Active storage pile (wind erosion and maintenance)	Limestone or overburden				A*EF			
			0.41	0.0041	ton/(hectare*yr)	8,200	82	2.6E-01	2.6E-03
9	Dump truck movement	Unpaved road	0.36*5.9(s/12)*(S/30)*(W/3)0.7 *w/4)^0.5*((365-p)/365)*281.11	0.095*5.9(s/12)*(S/30)*(W/3)0.7*w/4)^0.5*((365-p)/365)*281.12	g/VKT	VKT*EF			
			836	221		49,643	13,100	1.6E+00	4.2E-01
						Total with 30 % Suppression		1.4E+00	3.1E-01

Table 4.9 Emission Rate Calculation for Main and Ancillary Equipment during Limestone Mine Operation

No	Activity Data (A)						Emission Factor (EF)						Emission Rate				
	Equipment	Specification	Require-ment	Capa-city	Operating hours	Vehicle Mile Travel	PM_{10}	$PM_{2.5}$	CO	NO_x	SO_2	Unit	PM_{10}	$PM_{2.5}$	CO	NO_x	SO_2
			R		OH	VMT	EF						E				
				bhp	hours/ year	Mile/year							g/s				
1	Main Mining Equipment												E = (EF*Cap*OH*R)/(365*24*3600)				
	Drilling machine	385 Hp	3	379.61	3300		0.259	0.239	3.377	4.523	0.006	g/bhp-hr[a]	3.E-02	3.E-02	4.E-01	5.E-01	7.E-04
	Excavator with rock breaker	40 ton class, 175 Hp	1	172.55	3300		0.259	0.239	3.377	4.523	0.006	g/bhp-hr[a]	5.E-03	4.E-03	6.E-02	8.E-02	1.E-04
2	Loading												E = (EF*Cap*OH*R)/(365*24*3600)				
	Hydraulic excavator	4.5 m^3 bucket cap., 450 Hp	3	172.55	3300		0.259	0.239	3.377	4.523	0.006	g/bhp-hr[a]	1.E-02	1.E-02	2.E-01	2.E-01	3.E-04
	Loader	4 m^3 bucket, 350 Hp	1	246.5	3300		0.109	0.100	1.194	2.800	0.006	g/bhp-hr[a]	3.E-03	3.E-03	3.E-02	7.E-02	2.E-04
3	Transportation												E = (EF*OH*R)/(365*24*3600)				

No	Activity Data (A)						Emission Factor (EF)						Emission Rate				
	Equipment	Specification	Require-ment	Capa-city	Operating hours	Vehicle Mile Travel	PM_{10}	$PM_{2.5}$	CO	NO_x	SO_2	Unit	PM_{10}	$PM_{2.5}$	CO	NO_x	SO_2
			R		OH	VMT	EF						E				
				bhp	hours/ year	Mile/year							g/s				
	Off highway dump truck, HHDT	36 ton payload cap., 450 Hp	2		330		0.760	0.700	45.960	114.93	0.060	g/hr[a]	2.E-05	1.E-05	1.E-03	2.E-03	1.E-06
			8		2970		2.300	0.720	10.140	19.56	0.030	g/hr[a]	2.E-03	5.E-04	8.E-03	1.E-02	2.E-05
4	Ancillaries												E = (EF*Cap*OH*R)/(365*24*3600)				
	Bulldozer with ripper	300 – 350 Hp	1	345.1	3300		0.14	0.129	3.053	4.7	0.006	g/bhp-hr[a]	5.E-03	5.E-03	1.E-01	2.E-01	2.E-04
	Grader	140 – 150 hp	1	147.9	3300		0.26	0.239	3.369	5.1	0.006	g/bhp-hr[a]	4.E-03	4.E-03	5.E-02	8.E-02	9.E-05
													E = (0.45*1000*VMT*EF*R)/(365*24*3600)				
	Jeeps - Double Axle drive		2			36,828	5.0E-04	4.1E-04	1.2E-02	1.3E-02	3.E-05	pounds/mile[b]	5.E-04	4.E-04	1.E-02	1.E-02	3.E-05
	Water sprinkler (truck chassis mounted)		1			17,820	5.0E-04	4.1E-04	1.2E-02	1.3E-02	3.E-05	pounds/mile[b]	3.E-04	2.E-04	6.E-03	7.E-03	1.E-05
	Fuel tanker (truck chassi mounted)		1			17,820	5.0E-04	4.1E-04	1.2E-02	1.3E-02	3.E-05	pounds/mile[b]	3.E-04	2.E-04	6.E-03	7.E-03	1.E-05
	Mobile service van		1			36,828	9.3E-05	6.0E-05	6.1E-03	6.0E-04	1.E-05	pounds/mile[b]	5.E-05	3.E-05	3.E-03	3.E-04	6.E-06
					Total								6.E-02	6.E-02	9.E-01	1.E+00	2.E-03

Table 4.10 Emission Rate from Limestone Operation

No	Limestone Mine Operation	Emission Rate									
		PM_{10}	$PM_{2.5}$	CO	NO_x	SO_2	PM_{10}	$PM_{2.5}$	CO	NO_x	SO_2
		E					E2 = E / 500000				
		g/s					$g/s/m^2$				
1	Mining Activities (**Table 4.3**)	1.4E+00	3.1E-01				2.4E-06	5.4E-07			
2	Main and Ancillary Equipment (**Table 4.4**)	0.064	0.058	0.876	1.231	0.002	1.1E-07	1.0E-07	1.5E-06	2.1E-06	3.0E-09
						Total	2.5E-06	6.4E-07	1.5E-06	2.1E-06	3.0E-09

- *Particulate and gases from clay mine operation*

Table 4.11 Emission Rate Calculation for Clay Mine Operation

No	**Activity**								**Emission Factor**		**Emission Rate**	
	Activity Generating Particulate	Silt Con-tent	Vehicle Km Travelled	average weight of the vehicles	Mean number of wheels	Average wind speed	Mean vehicle speed	Number of days with at least 0.254 mm of precipitation per year	PM, £ 10mm	PM, £ 2,5mm	PM, £ 10mm	PM, £ 2,5mm
		s	VKT	W	w	U	S	p				
		%	VKT/year	ton		m/sec	km/hour				g/s	
1	Truck movement (limestone hauling)								$E = k\,5.9\left(\frac{s}{12}\right)\left(\frac{S}{30}\right)\left(\frac{W}{3}\right)^{0.7}\left(\frac{w}{4}\right)^{0.5}\left(\frac{365-p}{365}\right)$ K = 0.36 for PM_{10}, and 0.095 for $PM_{2.5}$			
		6.20	59,400	20.0	8	8	25	128	142	37	1.9E-01	4.9E-02
									Total with 30% Suppression		1.3E-01	3.4E-02

Table 4.12 Emission Rate Calculation for Main and Ancillary Equipment during Clay Mine Operation

No	Activity Data						Emission Factor (EF)						Emission Rate				
	Main and ancillary equipment	Cap	Requi-rement	Capa-city	Operating Hour	Vehicle mile travel	PM_{10}	$PM_{2.5}$	CO	NO_x	SO_2	Unit	PM_{10}	$PM_{2.5}$	CO	NO_x	SO_2
			R	Cap	OH	VMT	EF						E				
				BHP	hour/year	mile/year							g/s				
1	Hydraulic excavator												E = (EF*Cap*OH*R)/(365*24*3600)				
		3 m^3	1	172.55	3300		3.E-01	2.E-01	3.E+00	5.E+00	6.E-03	g/bhp-hr[a]	5.E-03	4.E-03	6.E-02	8.E-02	**1.E-04**
													E = (0.45*1000*VMT*EF*R)/(365*24*3600)				
2	Tippers	10 ton	20			41,450	5.0E-04	4.1E-04	1.2E-02	1.3E-02	3.E-05	pounds/ mile	6.E-03	5.E-03	1.E-01	2.E-01	3.E-04

No	Activity Data						Emission Factor (EF)						Emission Rate				
	Main and ancillary equipment	Cap	Requi-rement	Capa-city	Operating Hour	Vehicle mile travel	PM_{10}	$PM_{2.5}$	CO	NO_x	SO_2	Unit	PM_{10}	$PM_{2.5}$	CO	NO_x	SO_2
			R	Cap	OH	VMT	EF						E				
				BHP	hour/year	mile/year							g/s				
3	Water sprinkler (truck chassis mounted)		1			12,435	5.0E-04	4.1E-04	1.2E-02	1.3E-02	3.E-05	pounds/ mile	9.E-05	7.E-05	2.E-03	2.E-03	5.E-06
4	Fuel tanker (truck chassi mounted)		1	175		12,435	5.0E-04	4.1E-04	1.2E-02	1.3E-02	3.E-05	pounds/ mile	9.E-05	7.E-05	2.E-03	2.E-03	5.E-06
						Total							1.E-02	9.E-03	2.E-01	2.E-01	4.E-04

Table 4.13 Emission Rate from Clay Mine Operation

No	Clay Mine Operation	Emission Rate									
		PM_{10}	$PM_{2.5}$	CO	NO_x	SO_2	PM_{10}	$PM_{2.5}$	CO	NO_x	SO_2
		E					E2 =E/400633				
		g/s					$g/s/m^2$				
1	Mining activities (**Table 3.6**)	1.3E-01	3.4E-02				3.3E-07	8.6E-08			
2	Main and ancillary equipment (**Table 3.7**)	1.1E-02	9.3E-03	2.0E-01	2.4E-01	4.4E-04	2.7E-08	2.3E-08	5.1E-07	5.9E-07	1.1E-09
						Total	3.5E-07	1.1E-07	5.1E-07	5.9E-07	1.1E-09

- *Particulate and gases from clay hauling (clay mine to cement plant)*

Table 4.14 Emission Rate Calculation for Clay Hauling from Clay Mine to Cement Plant

No.	Tripper's Route	Road surface silt loading	Vehicle kilometre travelled	Average vehicle weight	Area	PM_{10}	$PM_{2.5}$	PM_{10}	$PM_{2.5}$	PM_{10}	$PM_{2.5}$
		Activity Data				Emission Factor		Emission Rate			
		sL	VKT	W	A	EF		E		E2	
		gram/m^2	km	ton	m^2	g/km/year		g/s		g/s/m2	
						$0{,}62*(sL)^{0.91}*(W)^{1.02}$	$0{,}15*(sL)^{0.91}*(W)^{1.02}$	E = (EF*VKT)/(365*24*3600)		E2=E/A	
1	Tripper's Route from Clay Mine to Cement Plant	50	32,145	10	122,507	228.3	55.2	0.2327	0.0563	5.E-07	4.E-12

Table 4.15 Emission Rate Calculation for Tipper's Fuel Combustion

No	Equipment	Cap	Require-ment	Vehicle mile travel (for all truck)	Area	PM_{10}	$PM_{2.5}$	CO	NO_x	SO_2	Unit	PM_{10}	$PM_{2.5}$	CO	NO_x	SO_2
	Activity Data					Emission Factor (EF)						Emission Rate				
			R	VMT	A	EF						E				
		ton		mile/year	m^2							g/s/m2				
												E = (0.45*1000*VMT*EF)/(365*24*3600)/A				
2	Tippers' fuel combustion	10	20	19,930	122,507	5.0E-04	4.1E-04	1.2E-02	1.3E-02	3.E-05	pounds/ mile	1.2E-09	9.6E-10	2.7E-08	3.0E-08	6.4E-11

Table 4.16 Emission Rate From Clay Hauling

No	Activity	PM_{10}	$PM_{2.5}$	CO	NO_2	SO_2
		Emission				
		g/s/m2				
1	Tripper's Route from Clay Mine to Cement Plant (**Table 3.9**)	5.E-07	4.E-12			
2	Tippers' fuel combustion (**Table 3.10**)	1.2E-09	9.6E-10	2.7E-08	3.0E-08	6.4E-11
	Total	5.E-07	1.E-09	2.7.E-08	3.0E-08	6.E-11

4.2 Prediction of Impacts on Air Quality

Prediction of impacts on air quality can be basically done by calculating the atmospheric air pollutants dispersion which depends on many interrelated factors, such as physical and chemical nature of effluents, meteorological characteristics of the environment, location of the source with relation to obstructions to air motion, and nature of the terrain downwind from the source. Therefore the availability of reliable and complete data shall produce a refined air dispersion modelling. Prediction of impacts on air quality due to construction and operation phase of cement plant was modelled by using the AERMOD VIEW software. Two major parts related to modelling can be classified into modelling input and modelling output.

4.2.1 Modelling Input

Important points for the modelling input area:

- Emission rates from each sources and their supporting physical descriptions

  Emission rates of particulates in the form of PM_{10} and $PM_{2.5}$, and emission rates of gases in the form of CO, NO_2, and SO_2 for each source were derived from previous inventory calculation

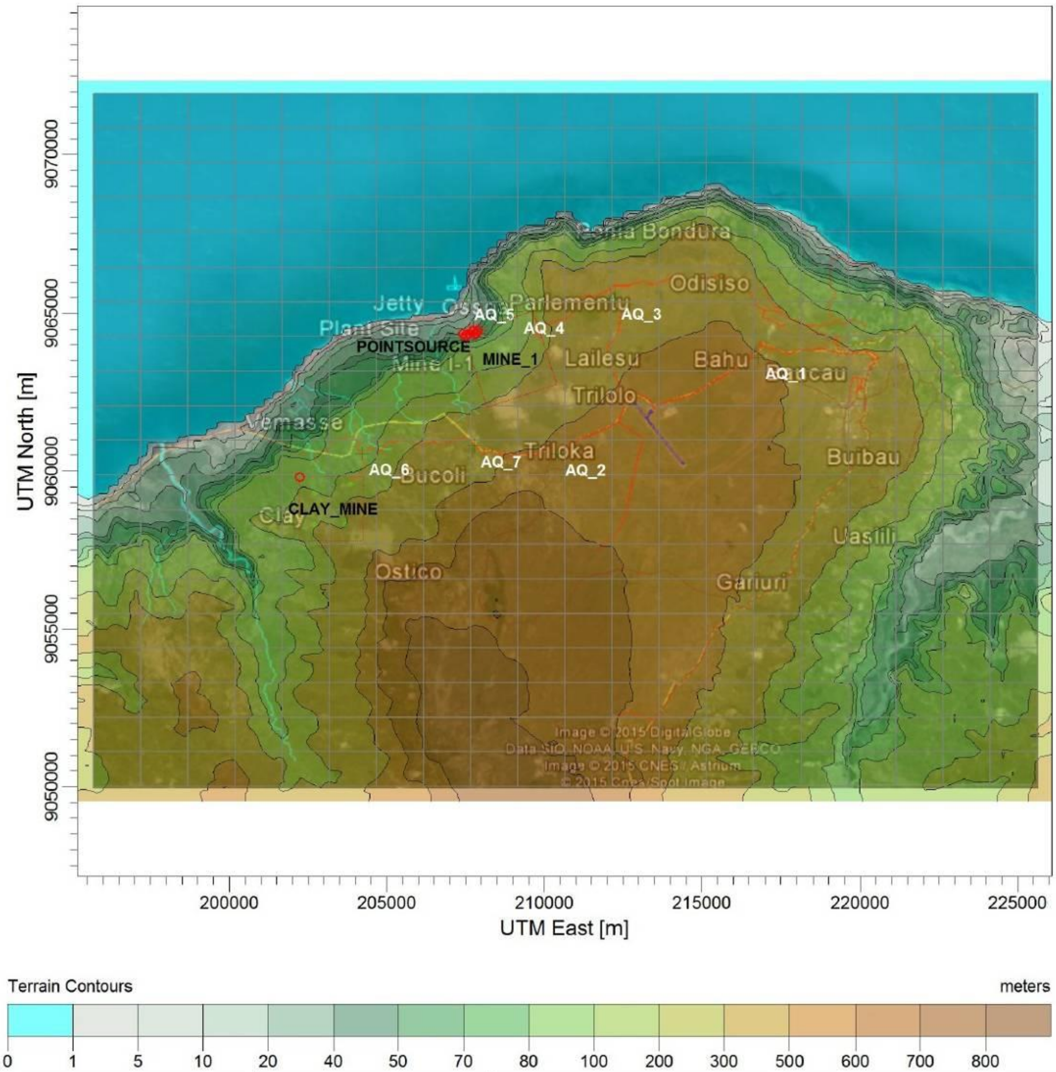
  - **Table 4.5** for construction phase
  - **Table 4.6**, **Table 4.10**, **Table 4.13**, and **Table 4.16** for operation phase.
- Location of sources, receptors including sensitive receptors, and topographical data of the model area. Main sources during the construction phase are located in cement plant and jetty area, limestone mine and clay mine. During the operation phase, the same main sources are also located in these areas, with additional line source of clay hauling (road route) from clay mine to cement plant area. Receptors are located up to 15 km from the source, with sensitive receptor denoted as AQ sign as already shown in **Table 3.1** and **Figure 4.1**. Receptors are denoted by grid for the uniform Cartesian grid (total: 448 receptors), and AQ sign for the discrete Cartesian receptors (total: 7 receptors).
- The map of the location uses the imagery map from Google earth which is directly connected with ISC AERMOD Software. The topographical map of the modelled area was extracted from *www.webgis.com*. This data was collected during the Shuttle Radar Topography Mission (SRTM) and contains global coverage from 56 degrees south latitude to 60 degrees north latitude in 1 by 1 degree blocks with an approximate resolution of 90 by 90 meters. The extracted topographical data in the form of the Shuttle Radar Topography Mission (SRTM) are divided into one by one degree latitude and longitude tiles in "geographic" projection. Heights are in meters referenced to the WGS84/EGM96 geoid. The file was then preprocessed using the AERMAP software to produce the calculated terrain elevation and scale height for each specified receptor as shown in **Figure 4.1.**
- Hourly meteorological data of temperature, pressure, humidity, and wind speed and wind direction, cloud cover.

  The surface and upper air meteorological data (hourly meteorological data of wind speed, wind direction, cloud cover, pressure, and temperature) for the modelled area were derived from lakes environmental software with the information shown in **Figure 3.5.**
- Background concentration, derived from baseline study

  The background concentrations were determined based on the baseline study before the operation of future cement plant. The predicted ground level concentration from the model results should be added with the background concentration to reflect the cumulative effect of emission from various sources within the study area.

Project Title

Terrain Contour, Emission Sources, and Receptors



Comments

Company Name

WorleyParsons - Resources and Energy

Modeler

EIA - Air Quality

SCALE: 1:194.239

0 5 km

WorleyParsons resources & energy

AERMOD View - Lakes Environmental Software

Source of terrain data: www.webgis.com

Figure 4.1 Emission Sources, Receptors, and Terrain Contour – Surrounding Project Area

4.2.2 Modelling output

Results of prediction are presented in the form of isopleth of each concentration over the receptor area. An isopleth map generalizes and simplifies a continuous distribution data. The data was presented as a third dimension map, which is indicated by series of lines called isopleths which connect points of equal value of concentration. The averaging time was chosen to be 1 hour (except for particulates), 24 hour and annual averaging time, since generally the air pollutant has the standard in this averaging time. Calculated concentration by the model shows the concentration that is merely caused by the construction activities, not include the background concentration (concentration before the activity begins, i.e. air quality baseline data). Therefore to approximate accumulative ambient impacts, background concentration has to be added to the predicted concentration.

Construction Phase

PM_{10} and $PM_{2.5}$

Construction phase is a source of dust emissions that may have substantial temporary impact on local air quality. Emissions during the construction can be associated with site preparation and operation of main and ancillary equipment, and construction the facilities. Construction works relates to earth moving during site preparation has the highest contribution to the particulate emission rates.

Isopleth **in Figure 4.2** and **Figure 4.3** shows PM_{10} tends to disperse to the north west direction from the construction area, the opposite direction from where the prevailing winds blow (**see Figure 3.5**, prevailing winds blows mostly blow from south east direction). Higher topographical level south east of mining and plant area also give contribution to hinder the dispersion to south east direction. A high concentration of PM_{10} will be concentrated in the mining area (limestone and clay construction work area) and cement-jetty plant area. The 24 hour average concentration of PM_{10} caused by construction activities is predicted to be as high as 114 µg/Nm^3 (**Figure 4.2**) about 4 times higher than its background concentration (PM_{10} concentration from baseline data: 21 up to 31 µg/Nm^3). The highest probable concentration due to cumulative impacts of 24 hour average concentration of PM_{10} is 145 µg/Nm^3. **Figure 4.3** shows the highest annual average concentration of PM_{10} is predicted to be 17 µg/Nm^3. Both averaging time concentration is lower than the standard (150 µg/Nm^3 for 24 hour average concentration and 70 µg/Nm^3 for annual average concentration).

Similar dispersion pattern shows in **Figure 4.4** and **Figure 4.5** for $PM_{2.5}$. The highest 24 average concentration for $PM_{2.5}$ is calculated to be 25 µg/Nm^3; slightly higher than its background (9 - 23 µg/Nm^3) which will give the highest cumulative impacts of 48 µg/Nm^3. The annual average of $PM_{2.5}$ concentration is calculated to be about 4 µg/Nm^3. All calculated and cumulative ambient concentration is predicted to be lower than the standard, 75 µg/Nm^3 for 24 hour average and 35 µg/Nm^3 for annual average. It should be noted that these predicted level of concentrations might be observed if construction works applied the control techniques to reduce the emission of particulates. Higher level of particulates may occur if particulate emission control is neglected.

Figure 4.2 until **Figure 4.4** also indicate that the sensitive receptors which might undergo higher level of concentrations than other sensitive receptors are located in AQ5 (around the jetty plant area, scattered small cluster of fisherman village close to this plant area), AQ4 (Aldeia Osso-ua, settlement close plant area), and AQ6 Wailacama (settlement area north east of clay quarry).

CO, NO_2, and SO_2

During construction phase, gases (CO, NO_2, and SO_2) might be emitted from the operation of heavy equipment and vehicle movement. Incomplete combustion in internal engine may emit certain amount of these pollutants. Dispersion estimates for these gases can be seen in **Figure 4.6 to 4.8** (for CO), **Figure 4.9** to **4.11**(for NO_2) and **Figure 4.12** to **4.14** ($SO_{2)}$). Similar to particulates, pollutants tend to disperse to North West of the sources, and higher concentrations are identified in cement-jetty plant area. Construction activities which emit these pollutants are concentrated in cement-jetty plant area. Therefore higher concentration might happen close to this area. The highest 1 hour average concentrations of CO, NO_2, and SO_2 are 287 µg/Nm^3, 109 µg/Nm^3, and 0.7 µg/Nm^3 respectively, all are below their ambient standards (CO: 40000 µg/Nm^3 , NO_2: 200 µg/Nm^3, and SO_2: 350 µg/Nm^3). Background concentration for CO, NO_2, and SO_2 are 218-418 µg/Nm^3, 7 - 28 µg/Nm^3, and 8.5 – 18 µg/Nm^3 respectively, which give the highest cumulative ambient concentrations of 705 µg/Nm^3 for CO, 137 µg/Nm^{3}for NO_2, and 18.7 µg/Nm^3 for SO_2. These cumulative ambient concentrations are also below the ambient standard for each pollutant. The summary of predicted 1st high 1 hour, 24 hour and annual concentration for each pollutant is presented in **Table 4.17** for construction phase and **Table 4.18** for operation phase.

Operation Phase

PM_{10} and $PM_{2.5}$

During the operation phase of cement plant, the main sources of dust are the stacks of the kiln system, cooler ESP, cement mill, coal mill, and thermal power plant. The emission rate of particulates from main stack sources will be maintained not more than 30 µg/Nm^3, using particulate control with very high reduction efficiency (up to 99%) such as bag filter and electrostatic precipitator. In addition some channelled dust emissions occur in connection with the various grinding processes (raw materials, cement), and diffuse dust emission may arise from storage and handling of raw materials, fuels, clinker and cement, as well as from vehicle traffic used at the manufacturing site. Other sources come from the mining activities, and clay hauling from clay mine to cement plant storage area. Dispersion estimates for PM_{10} are shown in **Figure 4.15** and **Figure 4.16,** while for PM $_{2.5}$ are shown in **Figure 4.17** and **Figure 4.18.** The dispersion direction is still similar to the construction phase, i.e. tends to the North West direction. Predicted 24 hour ambient concentration of PM_{10} and $PM_{2.5}$ are 30 µg/Nm^3 and 13 µg/Nm^3 respectively, which would lead to cumulative ambient concentration of 61 µg/Nm^3 for PM_{10} and 36 µg/Nm^3 for $PM_{2.5}$.These values are below the 24 hour average standard for each respective pollutant.

Maintaining the PM_{10} and $PM_{2.5}$ ambient concentration is very important because PM_{10} or $PM_{2.5}$ may contain microscopic solids or liquid droplets that are so small that they can get deep into the lungs and cause serious health problems. Numerous scientific studies have linked particle pollution exposure to a variety of problems, including: premature death in people with heart or lung disease, nonfatal heart attacks, irregular heartbeat, aggravated asthma, decreased lung function, and increased respiratory symptoms, such as irritation of the airways, coughing or difficulty breathing. People with heart or lung diseases, children and older adults are the most likely to be affected by particle pollution exposure.

CO, NO_2, and SO_2

The main source of gases comes from the combustion process in cement plant, power plant, and also in internal engine of heavy equipment and vehicle traffic. The specific sources may come from the following processes:

- CO can occur in the primary steps of the kiln process (preheater, precalciner), when impurities (such as organic matter) that are present in the raw materials are volatised as the raw mix is heated.
- NO_x are formed in the combustion process either by oxidation of the nitrogen in the combustion air (thermal NO_x), or by oxidation of the nitrogen compounds in the fuel (fuel NOx). Thermal NO_x form at temperatures above 1200˚C. Due to the very high temperatures in the cement kiln thermal NO_x dominate.
- SO_2 emissions from cement plants are primarily determined by the content of volatile sulphur in the raw materials. This sulphur is emitted as SO_2 from the low temperature end of the kiln system. Sulphur present as sulphates in the raw materials is only partly decomposed at high temperatures and almost completely discharged from the kiln system with the clinker. Sulphur introduced into the kiln with the fuels is oxidised to SO_2 and will not lead to significant SO2 emissions as SO2 formed at the hot end of the kiln system reacts with the reactive, fine raw materials in the sintering zone, the precalciner and the hot part of the preheater.
- Dispersion estimate during operation phase are shown in **Figure 4.19** to **Figure 4.21** for CO, **Figure 4.22** to **Figure 4.25** for NO_2, and **Figure 4.26** and **Figure 4.28** for SO_2.. The isopleth patterns show the tendency of pollutants to disperse to North West direction. During the operation phase, the gases seem to be able to disperse farther than during construction phase. The reason is because the dominant sources for these gases come from the cement plant operation (stack's sources) which has a higher height of discharge level (stack height itself). The predicted highest 1 hour average concentrations for these gases are: 659 µg/Nm^3 for CO, 222 µg/Nm^3 for NO_2, and 265 µg/Nm^3 for SO_2. Addition by background concentration would give cumulative ambient concentration of 1140 µg/Nm^3 for CO, 250 µg/Nm^3 for NO_2, and 283 µg/Nm^3 for SO_2. Cumulative ambient concentration of CO and SO_2 are still below the standard (CO:40000 µg/Nm^3 and SO2:350 µg/Nm^3). For NO_2 there is a probability exceedance (25 times) within a year, as shown in the output modelling which may violate the standard (see **Table 4.19.**)
- Maintaining CO, NO_2, and SO_2 concentration below the standard is very important, because high concentration of these pollutants may risk the human health. Higher concentration of these pollutants may occur during the dry season which last from July to November, because during these months wet deposition rarely happens.
  - The highest predicted 1 hour CO concentration (i.e., 1140 µg/Nm^3) is far lower than the harmful concentration. CO can cause harmful health effects by reducing oxygen delivery to the body's organs (like the heart and brain) and tissues. At extremely high levels, CO can cause death. Exposure to CO can reduce the oxygen-carrying capacity of the blood. As CO levels increase and remain above 50 ppm (57000 µg/Nm^3), symptoms may become noticeable. At levels approaching 200 ppm (230000 µg/Nm^3), symptoms become more severe. A concentration of 400 ppm (467000 µg/Nm^3) will further intensify symptoms and is life threatening after three hours of exposure while 800 ppm (915000 µg/Nm^3) results in unconsciousness within two hours and death within two to three hours. Exposure to about 13,000 ppm of CO can cause death after one to three minutes.
  - The highest predicted 1 hour NO_2 concentration (i.e., 250 µg/Nm^3) is also lower than the harmful concentration. The main effect of breathing in raised levels of NO_2 the increased likelihood of respiratory problems. Nitrogen dioxide inflames the lining of the lungs, and it can reduce immunity to lung infections. This can cause problems such as wheezing, coughing, colds, flu and bronchitis. Increased levels of nitrogen dioxide can have significant impacts on people with asthma because it can cause more frequent and more intense attacks. Children with asthma and older people with heart disease are most at risk. Available data from animal

toxicology experiments rarely indicate the effects of acute exposure to NO_2 concentrations of less than 1880 µg/Nm^3 (1 ppm). Normal healthy people exposed at rest or with light exercise for less than 2 hours to concentrations of more than 4700 µg/Nm^3 (2.5 ppm) experience pronounced decrements in pulmonary function; generally, such people are not affected at less than 1880 µg/Nm^3 (1 ppm). One study showed that the lung function of people with chronic obstructive pulmonary disease is slightly affected by a 3.75-hour exposure to 560 µg/Nm^3 (0.3 ppm). A wide range of findings in asthmatics has been reported; one study observed no effects from a 75-minute exposure to 7520 µg/Nm^3 (4 ppm), whereas others showed decreases in FEV1 after 10 minutes of exercise during exposure to 560 µg/Nm^3 (0.3 ppm). Asthmatics are likely to be the most sensitive subjects, although uncertainties exist in the health database. The lowest concentration causing effects on pulmonary function was reported from two laboratories that exposed mild asthmatics for 30–110 minutes to 560 µg/Nm^3 (0.3 ppm) during intermittent exercise. However, neither of these laboratories was able to replicate these responses with a larger group of asthmatic subjects. One of these studies indicated that nitrogen dioxide can increase airway reactivity to cold air in asthmatics. At lower concentrations, the pulmonary function of asthmatics was not changed significantly (WHO, 2000)

- The highest predicted 1 hour SO_2 concentration (i.e., 283 µg/Nm^3) is also lower than the harmful concentration. Scientific evidence links short-term exposures to SO_2, ranging from 5 minutes to 24 hours, with an array of adverse respiratory effects including bronchoconstriction and increased asthma symptoms. Asthmatic individuals are especially sensitive to SO_2 (Baxter, 2000) and may respond to concentrations as low as 0.2-0.5 ppm (525 – 1306 µg/Nm^3). Studies also show a connection between short-term exposure and increased visits to emergency departments and hospital admissions for respiratory illnesses, particularly in at-risk populations including children, the elderly, and asthmatics. Sulfur dioxide affects human health when it is breathed in. It irritates the nose, throat, and airways to cause coughing, wheezing, shortness of breath, or a tight feeling around the chest. The effects of sulfur dioxide are felt very quickly and most people would feel the worst symptoms in 10 or 15 minutes after breathing it in. Those most at risk of developing problems if they are exposed to sulfur dioxide are people with asthma or similar conditions.

Table 4.17 Predicted 1st High Air Pollutant Concentration for One Hour, 24 Hours, and Annual Average Concentration during Construction Phase

No.	Parameter	Averaging time	Standard	Modelling Output				
				1st High Concentration	Coordinate Location		Description Area	Figure Number
			μg/Nm³	μg/Nm³	Easting	Northing		
1	PM_{10}	24 hours	150	114	203171.72	9058782,81	Mining and cement plant area, north west of sources	Figure 3.2
		Annual	70	17	203171.72	9058782,81		Figure 3.3
2	$PM_{2.5}$	24 hours	75	25	203171.72	9058782,81		Figure 3.4
		Annual	35	3.81	203171.72	9058782,81		Figure 3.5
3	CO	1 hour	40000	287	207662,54	9065361,09	Plant and Jetty area, north west of sources	Figure 3.6
		24 hours		73	207662,54	9065361,09		Figure 3.7
		Annual		4.67	207662,54	9065361,09		Figure 3.8
4	NO_2	1 hour	200	109	207662,54	9065361,09		Figure 3.9
		24 hours		28	207662,54	9065361,09		Figure 3.10
		Annual	40	1.96	207662,54	9065361,09		Figure 3.11
5	SO_2	1 hour	350	0.7	207662,54	9065361,09		Figure 3.12
		24 hours	125	0.2	207662,54	9065361,09		Figure 3.13
		Annual		0.012	207662,54	9065361,09		Figure 3.14

Note: Predicted ambient concentration was calculated based on controlled emission rate (reduced emission rate by pollutant control from specified activities)

Table 4.18. Predicted 1st High Air Pollutant Concentration for One Hour, 24 Hours, and Annual Average Concentration during Operation Phase

No.	Parameter	Averaging time	Standard	Modelling Output				
				1st High Concentration µg/Nm³	Coordinate Location		Distance from the Source	Figure Number
					Easting	Northing		
1	PM_{10}	24 hour	150	30	209159.48	9064264.71	Inside mining area, north west of emission source	Figure 3.15
		Annual	70	5	209159.48	9064264.71		Figure 3.16
2	$PM_{2.5}$	24 hours	75	13	209159.48	9064264.71		Figure 3.17
		Annual	35	1,11	203171.72	9058782.81		Figure 3.18
3	CO	1 hour	40000	659	207662.54	9062071.64	Area between clay and limestone mine, north west of line source area	Figure 3.19
		24 hours		100	207662.54	9062071.64		Figure 3.20
		Annual		6	207662.54	9062071.64		Figure 3.21
4	NO_2	1 hour	200	222	209159.48	9064264.71		Figure 3.22 Figure 3.23
		24 hours		44	209159.48	9064264.71		Figure 3.24
		Annual	40	6	203171,72	9058782,81		Figure 3.25
5	SO_2	1 hour	350	265	207662.54	9062071.95		Figure 3.26
		24 hours	125	40	207662.54	9062071.95		Figure 3.27
		Annual		1,66	206165.60	906657.47		Figure 3.28

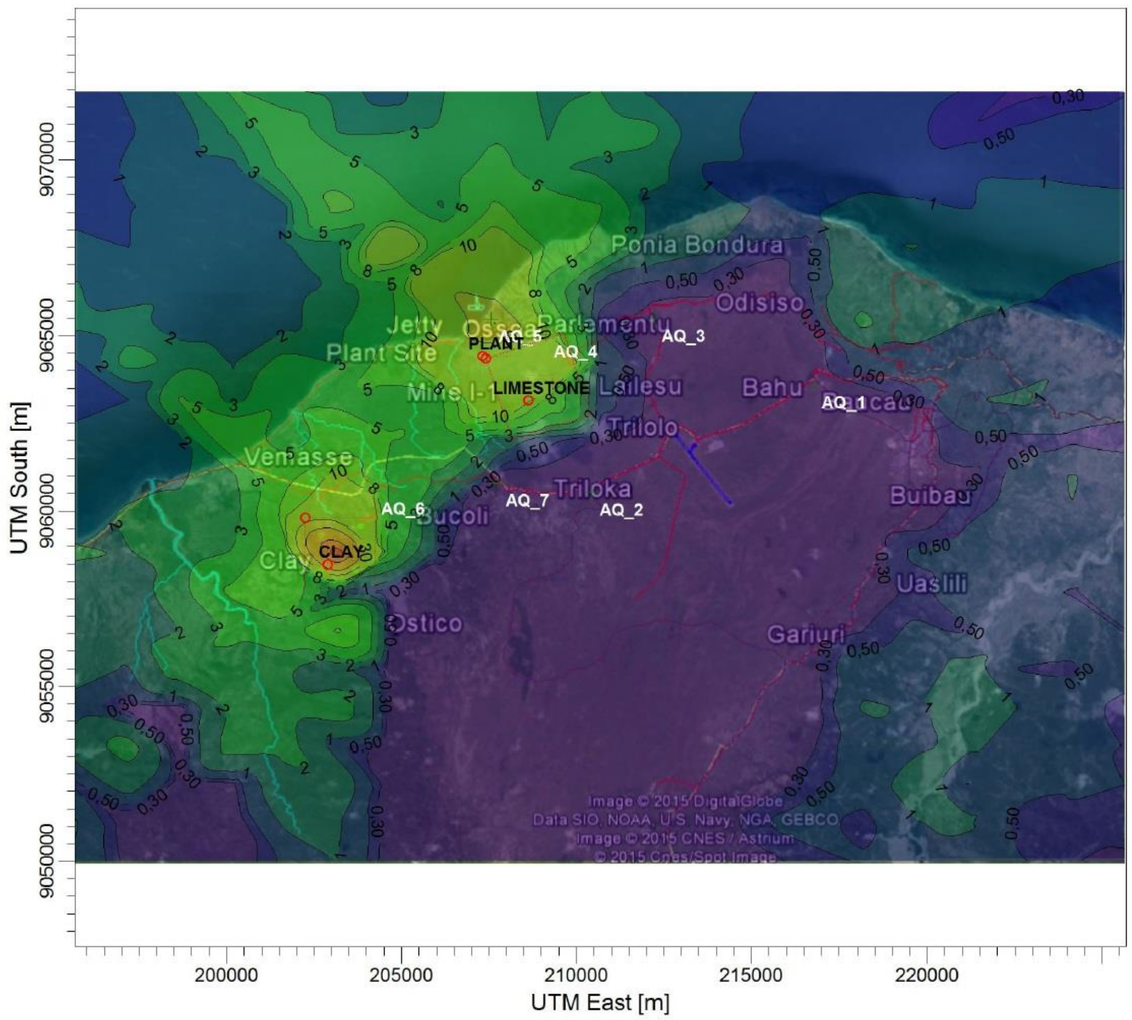
Note: Predicted ambient concentration was calculated based on controlled emission rate (reduced emission rate by pollutant control from specified activities)

Table 4.19 Predicted 1 Hour NO_2 Concentration Exceed the Ambient Standard (Modelling Output)

```
MAXI-FILE FOR  1-HR VALUES >= A THRESHOLD OF    200.0
FOR SOURCE GROUP: ALL
FORMAT: (1X,I3,1X,A8,1X,I8.8,2(1X,F13.5),3(1X,F7.2),1X,F13.5)
AVE   GRP          X              Y         AVERAGE CONC
___  _______   _____________  _____________  _____________
  1 ALL        209159.48000 9064264.71000     222.51581
  1 ALL        209159.48000 9064264.71000     213.56789
  1 ALL        209159.48000 9064264.71000     216.79533
  1 ALL        209159.48000 9064264.71000     216.77803
  1 ALL        209159.48000 9064264.71000     221.27082
  1 ALL        209159.48000 9064264.71000     221.55026
  1 ALL        209159.48000 9064264.71000     219.84058
  1 ALL        209159.48000 9064264.71000     204.79724
  1 ALL        209159.48000 9064264.71000     220.38416
  1 ALL        209159.48000 9064264.71000     216.21911
  1 ALL        207662.54000 9062071.95000     214.35220
  1 ALL        209159.48000 9064264.71000     216.99620
  1 ALL        209159.48000 9064264.71000     217.80108
  1 ALL        209159.48000 9064264.71000     212.02078
  1 ALL        209159.48000 9064264.71000     216.91408
  1 ALL        207662.54000 9062071.95000     213.34014
  1 ALL        209159.48000 9064264.71000     214.94832
  1 ALL        209159.48000 9064264.71000     203.56191
  1 ALL        209159.48000 9064264.71000     215.40348
  1 ALL        209159.48000 9064264.71000     211.43419
  1 ALL        209159.48000 9064264.71000     219.18460
  1 ALL        209159.48000 9064264.71000     213.12281
  1 ALL        209159.48000 9064264.71000     210.04060
  1 ALL        207662.54000 9062071.95000     203.20043
  1 ALL        209159.48000 9064264.71000     209.94019
  CONCUNIT ug/m^3
```

Project Title

PM10 - 1st High 24 Hour Ambient Concentration (Construction Phase)



PLOT FILE OF HIGH 1ST HIGH 24-HR VALUES FOR SOURCE GROUP: ALL ug/m^3

0,01 0,30 0,50 1,00 2,00 3,00 5,00 8,00 10,00 30,00 50,00 80,00 100,00 114,00

Comments Construction Phase		Company Name **WorleyParsons - Resources and Energy**
		Modeler **EIA - Air Quality**
	Output Type **Concentration**	SCALE: 1:188.674 0 5 km
	Maximum Concentration **114,25073 ug/m^3**	

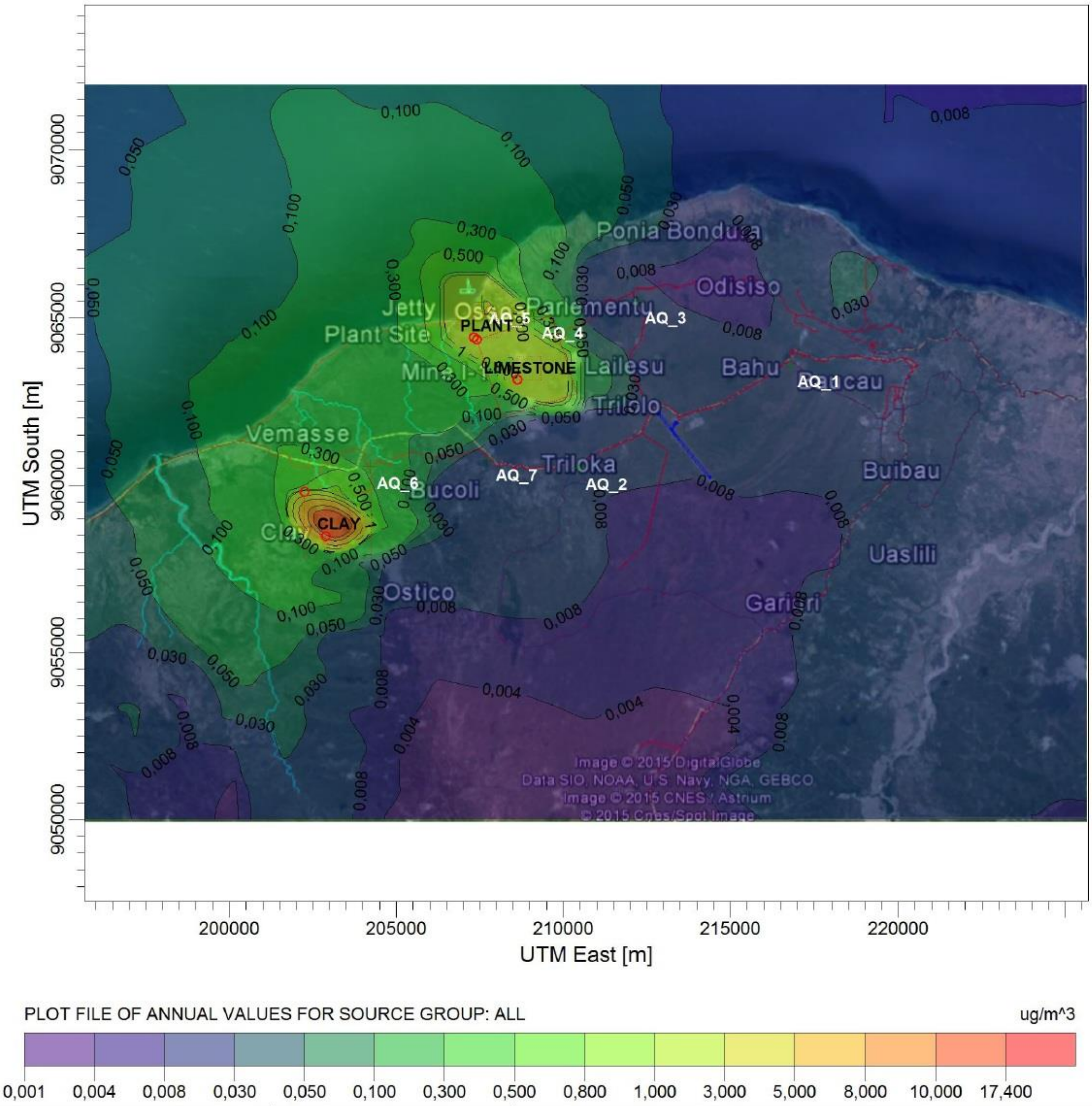
WorleyParsons resources & energy

AERMOD View - Lakes Environmental Software

Figure 4.2 PM_{10} - 1st High 24 Hour Ambient Concentration (Construction Phase)

Project Title

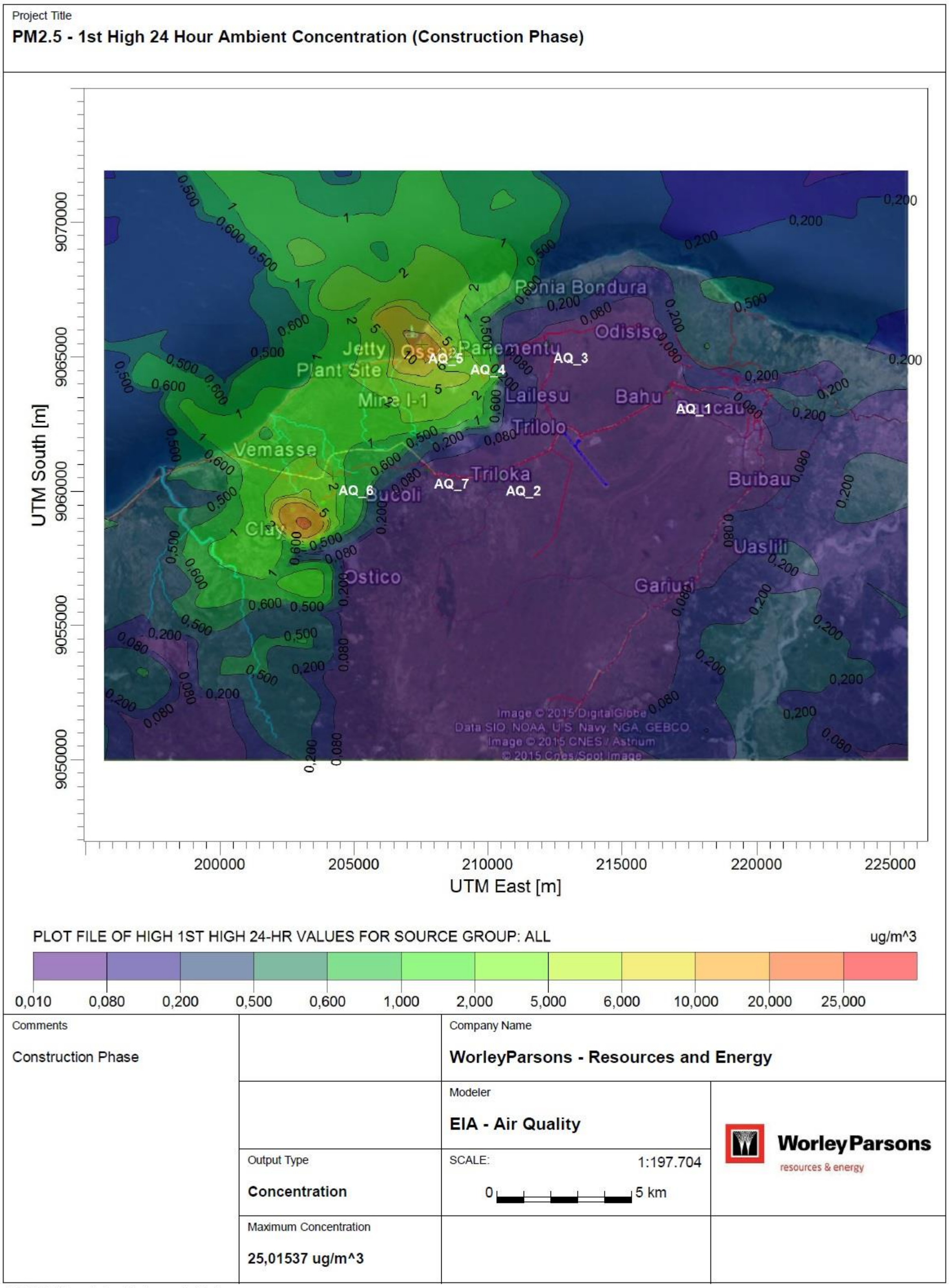
PM10 - 1st High Annual Ambient Concentration (Construction Phase)



Comments Construction Phase		Company Name **WorleyParsons - Resources and Energy**	
		Modeler **EIA - Air Quality**	WorleyParsons resources & energy
	Output Type **Concentration**	SCALE: 1:188.674 0 — 5 km	
	Maximum Concentration **17,40285 ug/m^3**		

AERMOD View - Lakes Environmental Software

Figure 4.3 PM_{10} - 1st High Annual Ambient Concentration



AERMOD View - Lakes Environmental Software

Figure 4.4 $PM_{2.5}$ - 1^{st} High 24 Hour Ambient Concentration (Construction Phase)

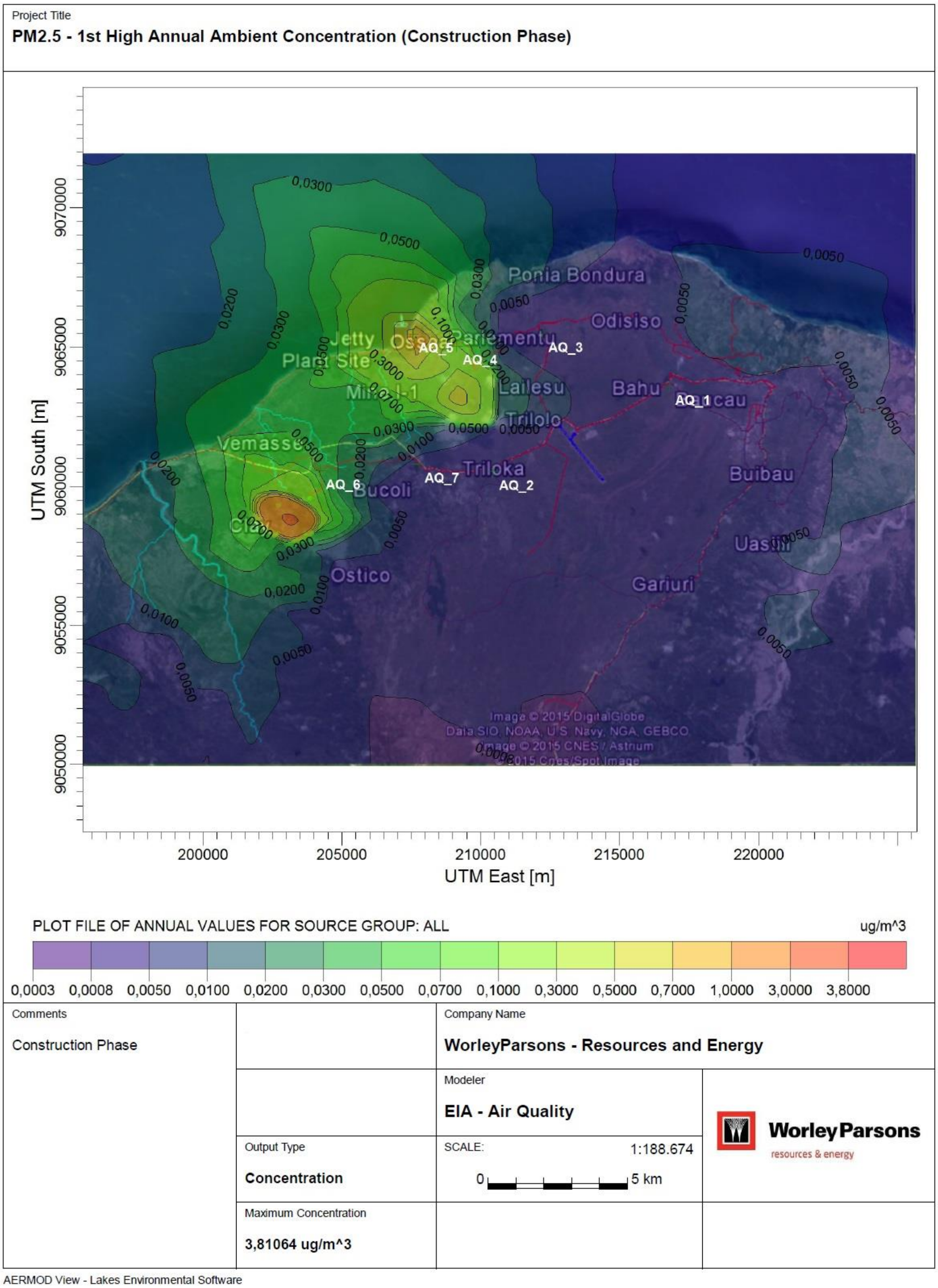
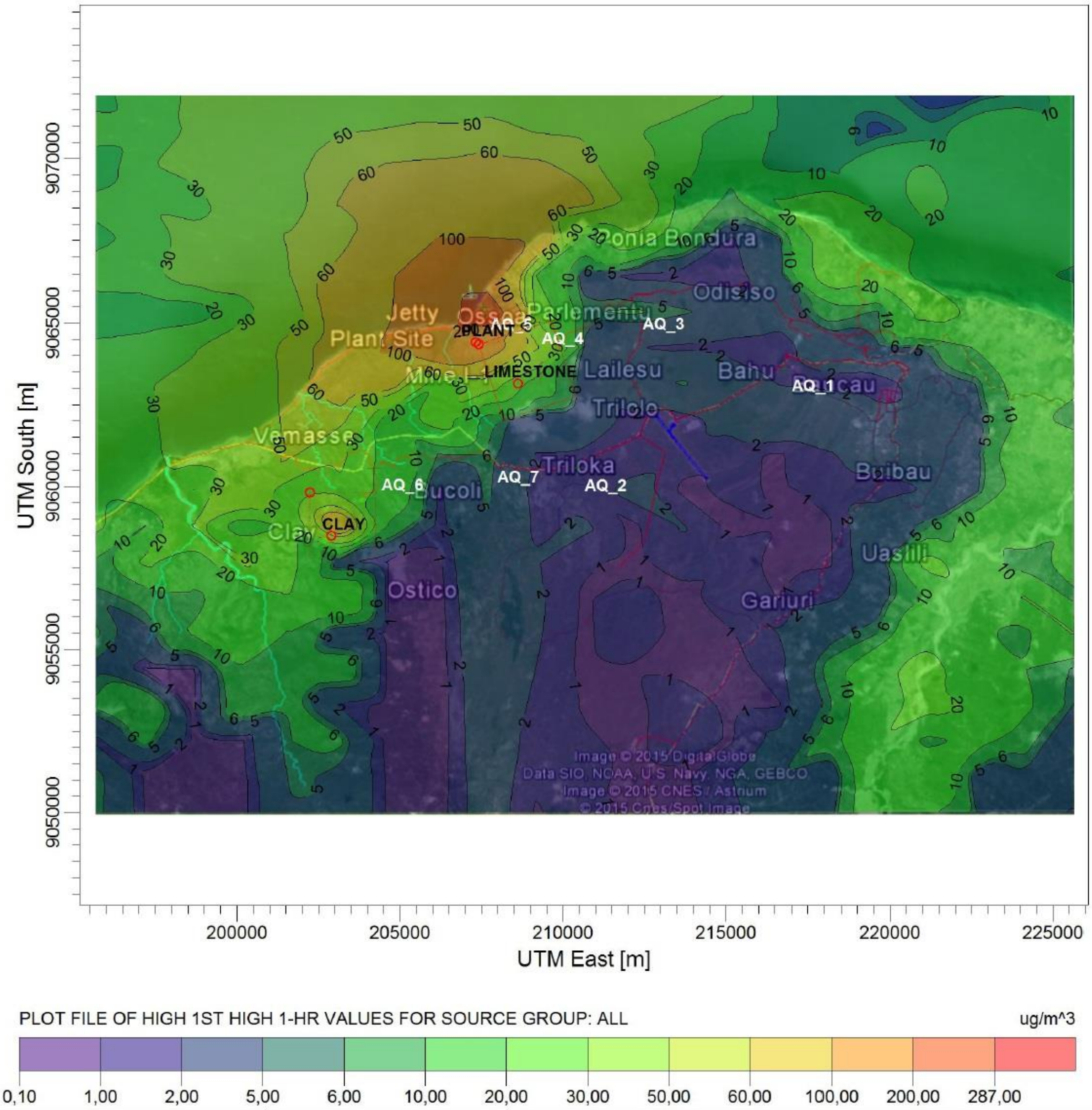


Figure 4.5 $PM_{2.5}$ - 1st High Annual Ambient Concentration (Construction Phase)

Project Title

CO - 1st High 1 Hour Ambient Concentration (Construction Phase)



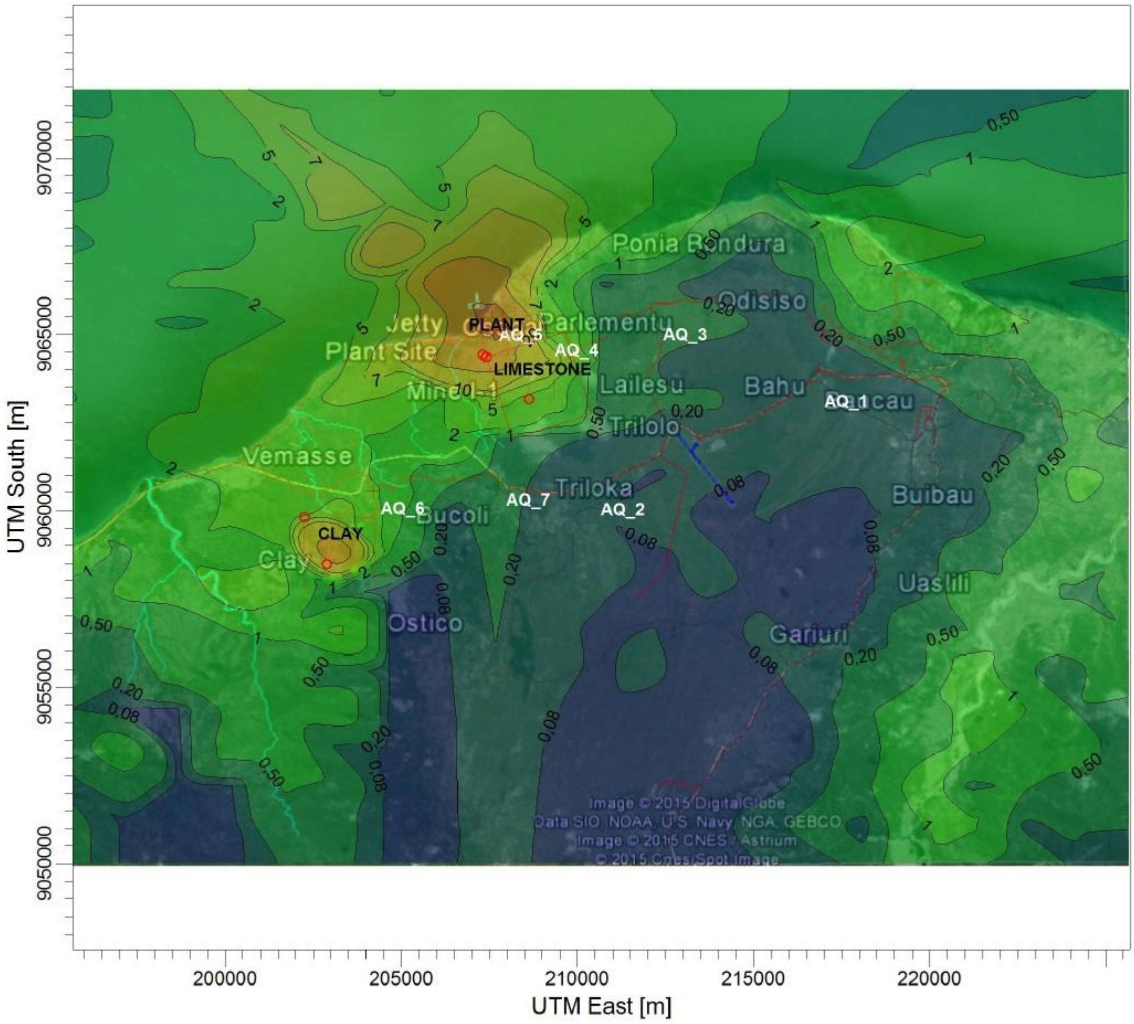
Comments		Company Name	
Construction Phase		**WorleyParsons - Resources and Energy**	
		Modeler **EIA - Air Quality**	WorleyParsons resources & energy
	Output Type **Concentration**	SCALE: 1:194.239 0 — 5 km	
	Maximum Concentration **287,36301 ug/m^3**		

AERMOD View - Lakes Environmental Software

Figure 4.6 CO - 1st 1 High Hour Ambient Concentration (Construction Phase)

Project Title

CO - 1st High 24 Hour Ambient Concentration (Construction Phase)



PLOT FILE OF HIGH 1ST HIGH 24-HR VALUES FOR SOURCE GROUP: ALL ug/m^3

0,01 0,02 0,08 0,20 0,50 1,00 2,00 5,00 7,00 10,00 20,00 50,00 70,00 73,30

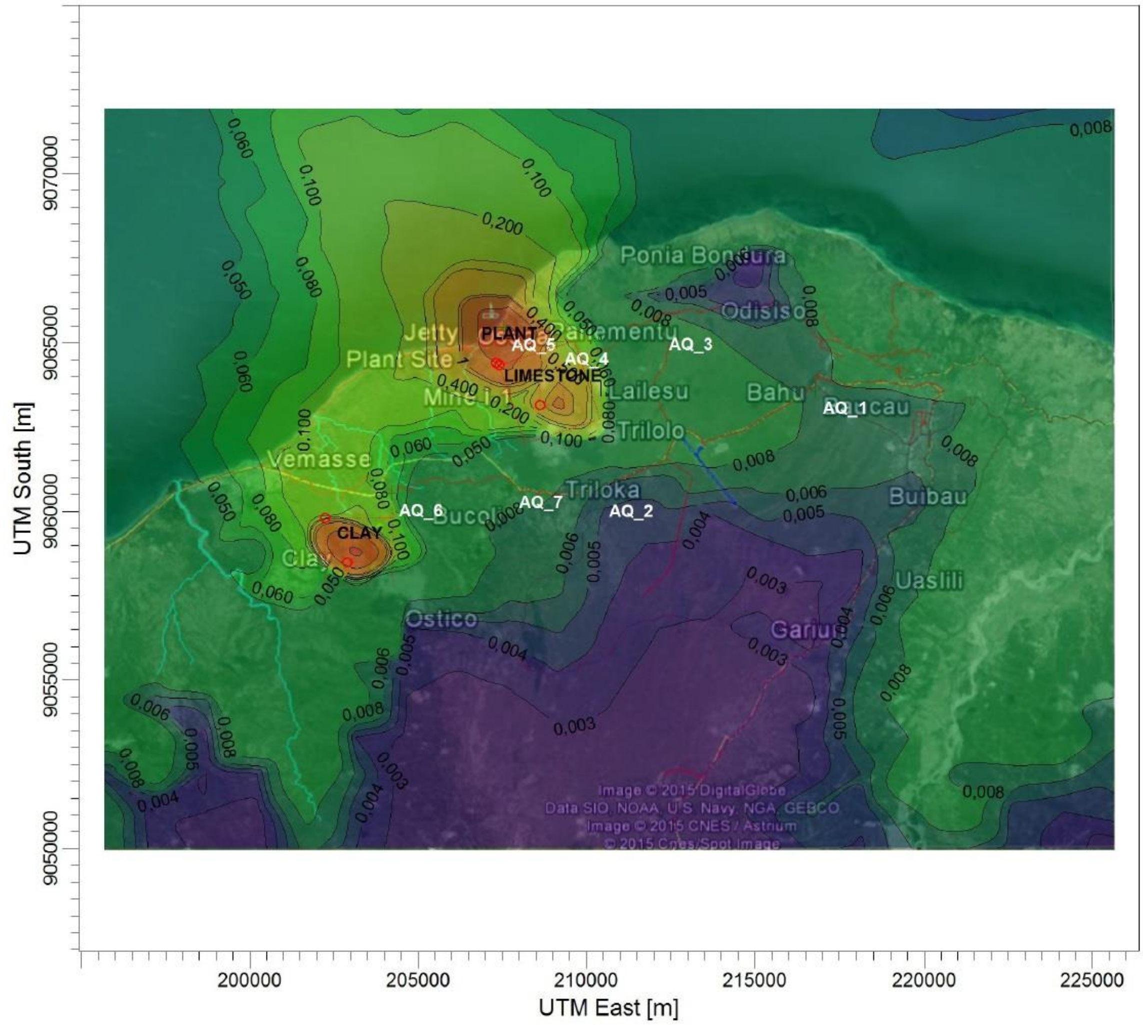
Comments Construction Phase		Company Name **WorleyParsons - Resources and Energy**	
		Modeler **EIA - Air Quality**	WorleyParsons resources & energy
	Output Type **Concentration**	SCALE: 1:188.674 0 — 5 km	
	Maximum Concentration **73,33923 ug/m^3**		

AERMOD View - Lakes Environmental Software

Figure 4.7 CO - 1st 24 High Hour Ambient Concentration (Construction Phase)

Project Title

CO - 1st High Annual Ambient Concentration (Construction Phase)



PLOT FILE OF ANNUAL VALUES FOR SOURCE GROUP: ALL ug/m^3

0,001 0,003 0,004 0,005 0,006 0,008 0,050 0,060 0,080 0,100 0,200 0,400 0,500 0,800 1,000 2,000 4,000 4,700

Comments Construction Phase		Company Name **WorleyParsons - Resources and Energy**
		Modeler **EIA - Air Quality**
	Output Type **Concentration**	SCALE: 1:197.704 0 5 km
	Maximum Concentration **4,67284 ug/m^3**	

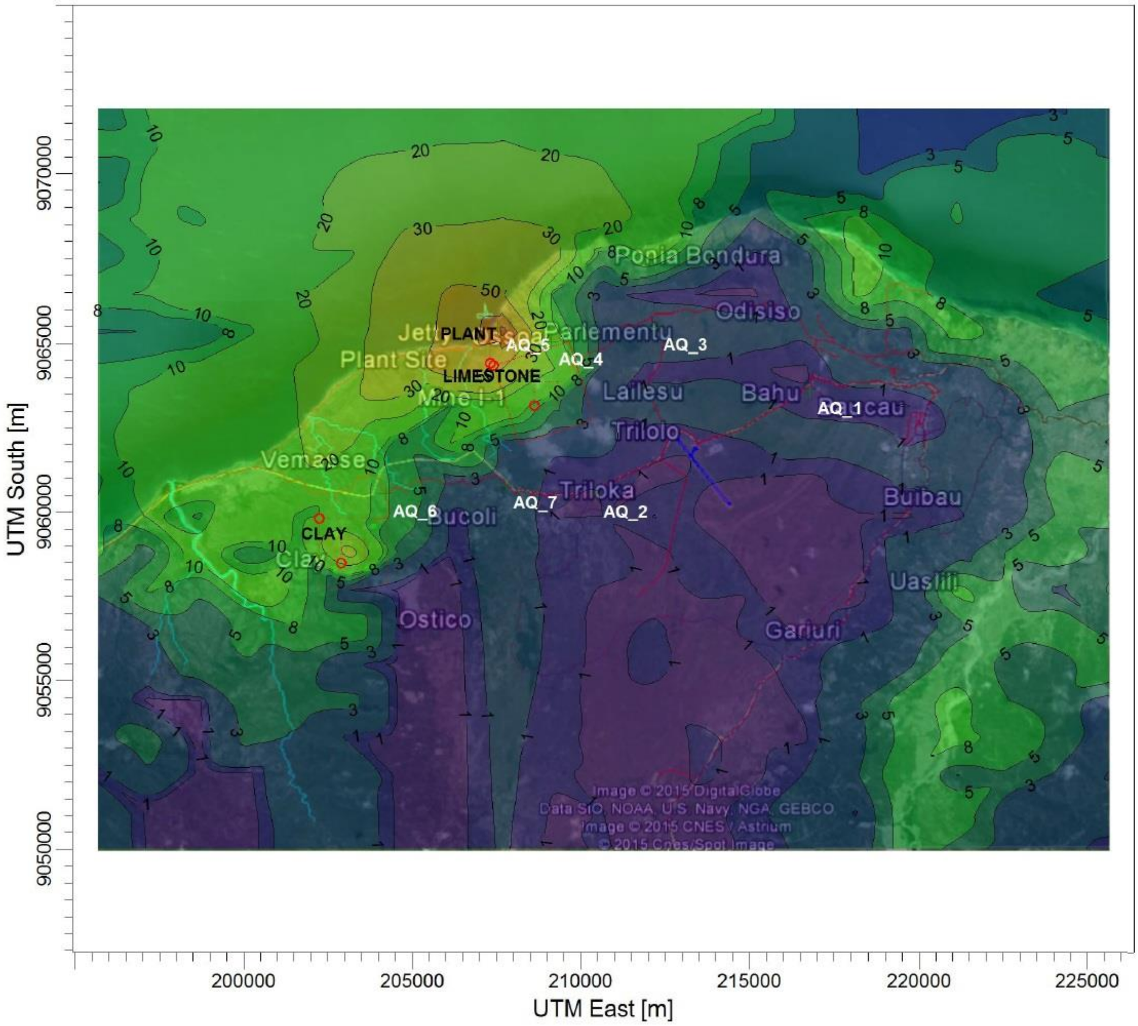
WorleyParsons resources & energy

AERMOD View - Lakes Environmental Software

Figure 4.8 CO - 1st High Annual Ambient Concentration (Construction Phase)

Project Title

NO2 - 1st High 1 Hour Ambient Concentration



PLOT FILE OF HIGH 1ST HIGH 1-HR VALUES FOR SOURCE GROUP: ALL — ug/m^3

0 | 1 | 1 | 3 | 5 | 8 | 10 | 20 | 30 | 50 | 80 | 100 | 109

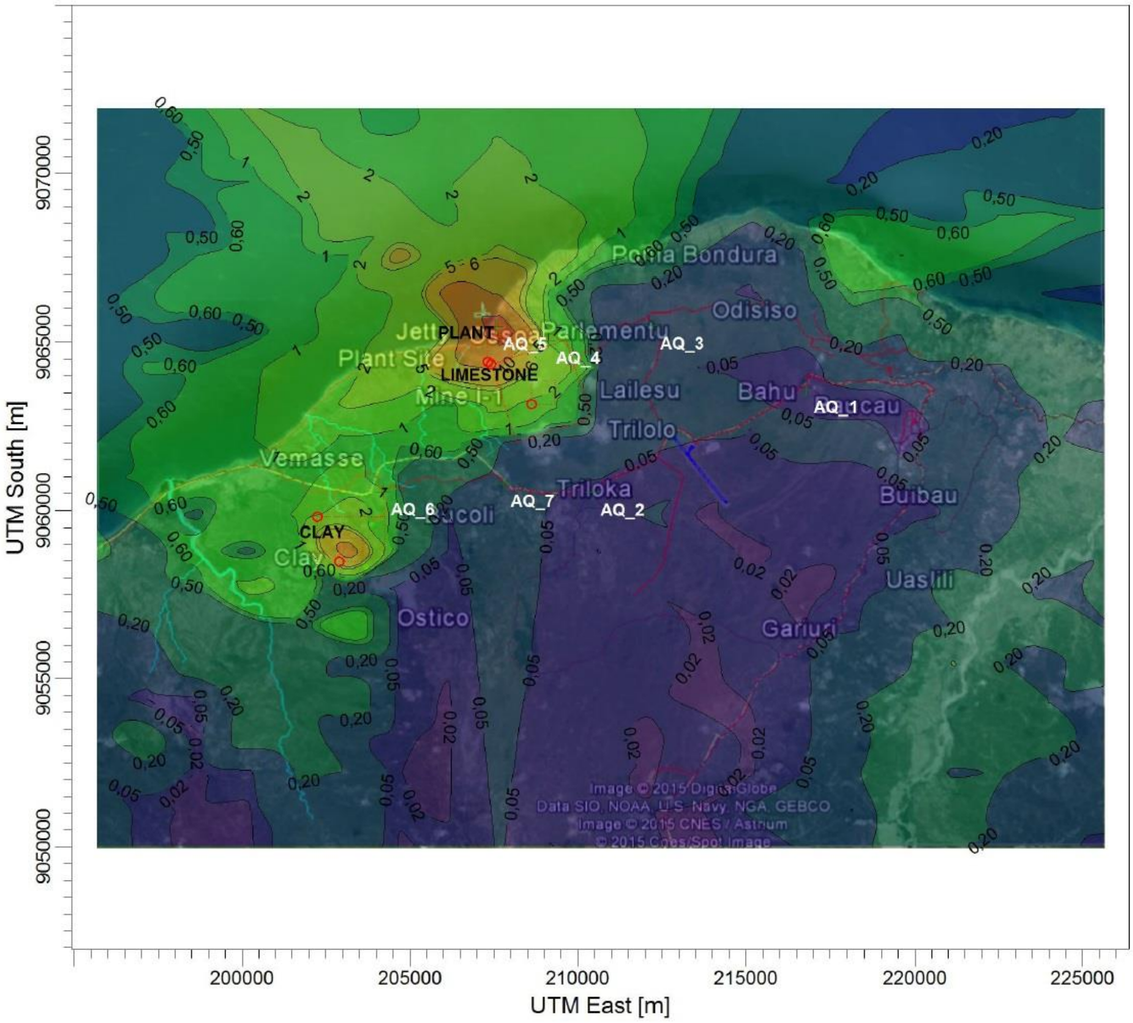
Comments		Company Name: **WorleyParsons - Resources and Energy**	
		Modeler: **EIA - Air Quality**	WorleyParsons resources & energy
	Output Type: **Concentration**	SCALE: 1:197.704 (0 — 5 km)	
	Maximum Concentration: **108,99976 ug/m^3**		

AERMOD View - Lakes Environmental Software

Figure 4.9 NO_2 - 1st High 1 Hour Ambient Concentration (Construction Phase)

Project Title

NO2 - 1st High 24 Hour Ambient Concentration (Construction Phase)



PLOT FILE OF HIGH 1ST HIGH 24-HR VALUES FOR SOURCE GROUP: ALL ug/m^3

0,01 0,02 0,05 0,20 0,50 0,60 1,00 2,00 5,00 6,00 10,00 20,00 28,00

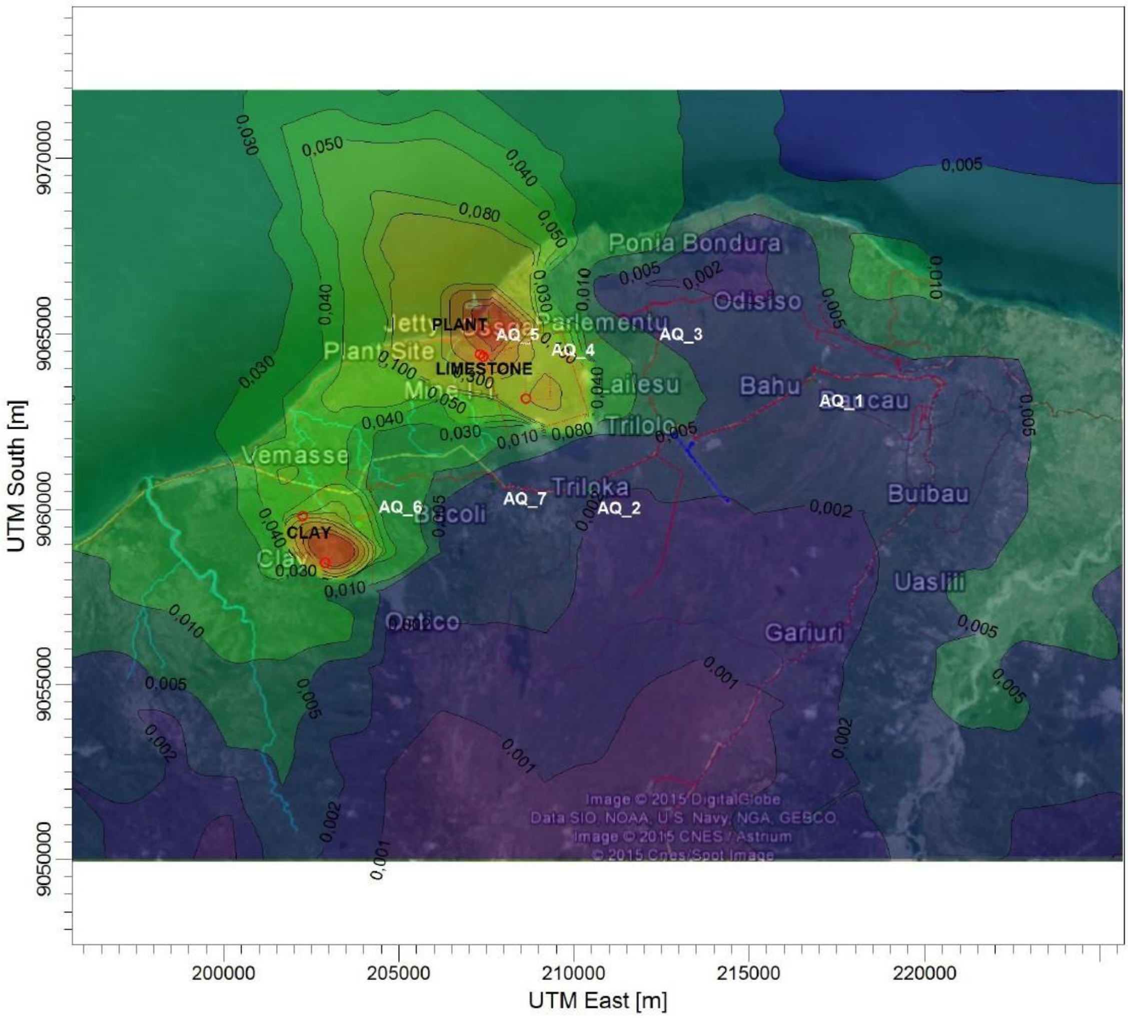
Comments		Company Name	
Construction Phase		**WorleyParsons - Resources and Energy**	
		Modeler **EIA - Air Quality**	WorleyParsons resources & energy
	Output Type **Concentration**	SCALE: 1:197.704 0 — 5 km	
	Maximum Concentration **27,81857 ug/m^3**		

AERMOD View - Lakes Environmental Software

Figure 4.10 NO_2 - 1st High 24 Hour Ambient Concentration (Construction Phase)

Project Title

NO2 - 1st High Annual Ambient Concentration (Construction Phase)



PLOT FILE OF ANNUAL VALUES FOR SOURCE GROUP: ALL — ug/m^3

0,0005 0,0010 0,0020 0,0050 0,0100 0,0300 0,0400 0,0500 0,0800 0,1000 0,3000 0,5000 0,8000 1,0000 2,0000

Comments: Construction Phase

Company Name: **WorleyParsons - Resources and Energy**

Modeler: **EIA - Air Quality**

Output Type: **Concentration**

SCALE: 1:188.674 (0 – 5 km)

Maximum Concentration: **1,95905 ug/m^3**

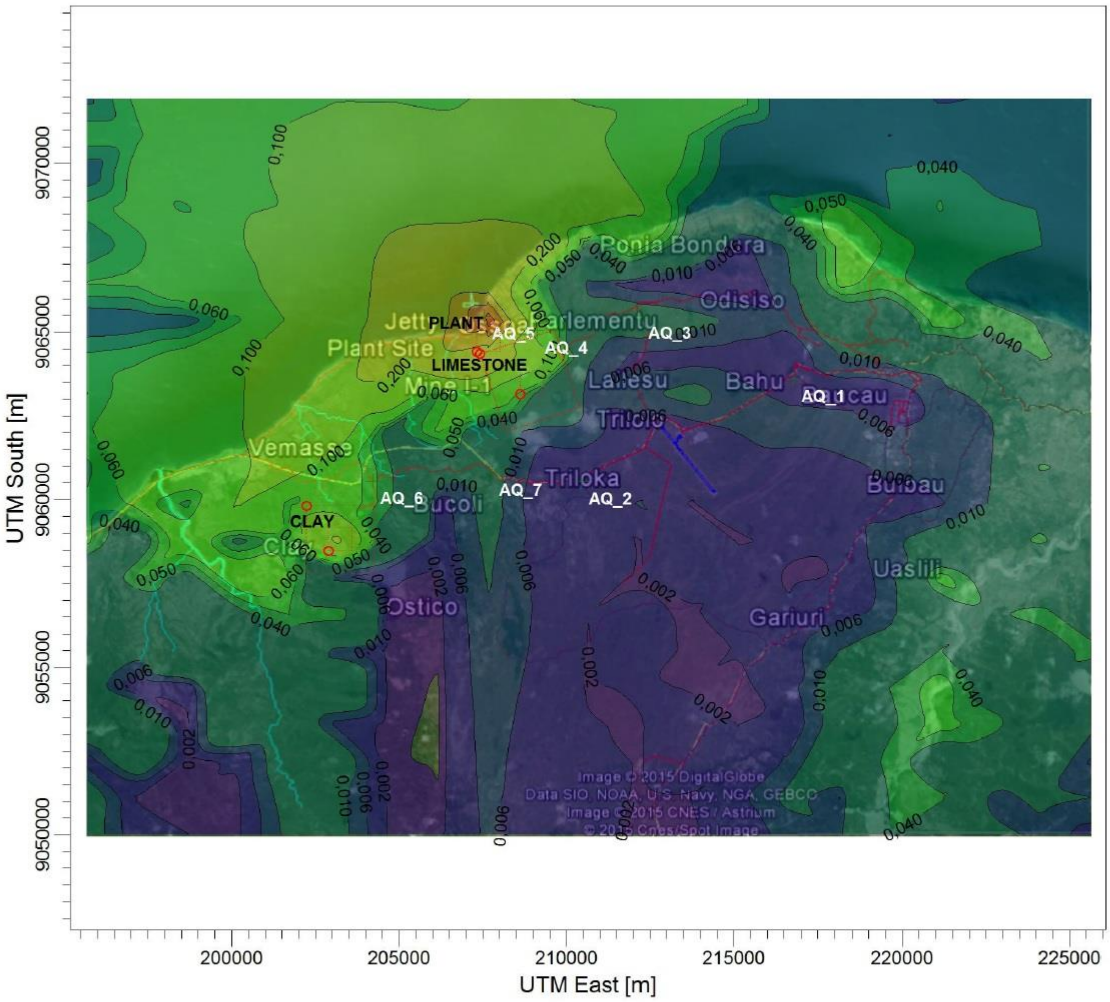
WorleyParsons resources & energy

AERMOD View - Lakes Environmental Software

Figure 4.11 NO_2 - High 1st Annual Ambient Concentration (Construction Phase)

Project Title

SO2 - 1st High 1 Hour Ambient Concentration (Construction Phase)



PLOT FILE OF HIGH 1ST HIGH 1-HR VALUES FOR SOURCE GROUP: ALL — ug/m^3

0,001 0,002 0,006 0,010 0,040 0,050 0,060 0,100 0,200 0,400 0,500 0,600 0,700

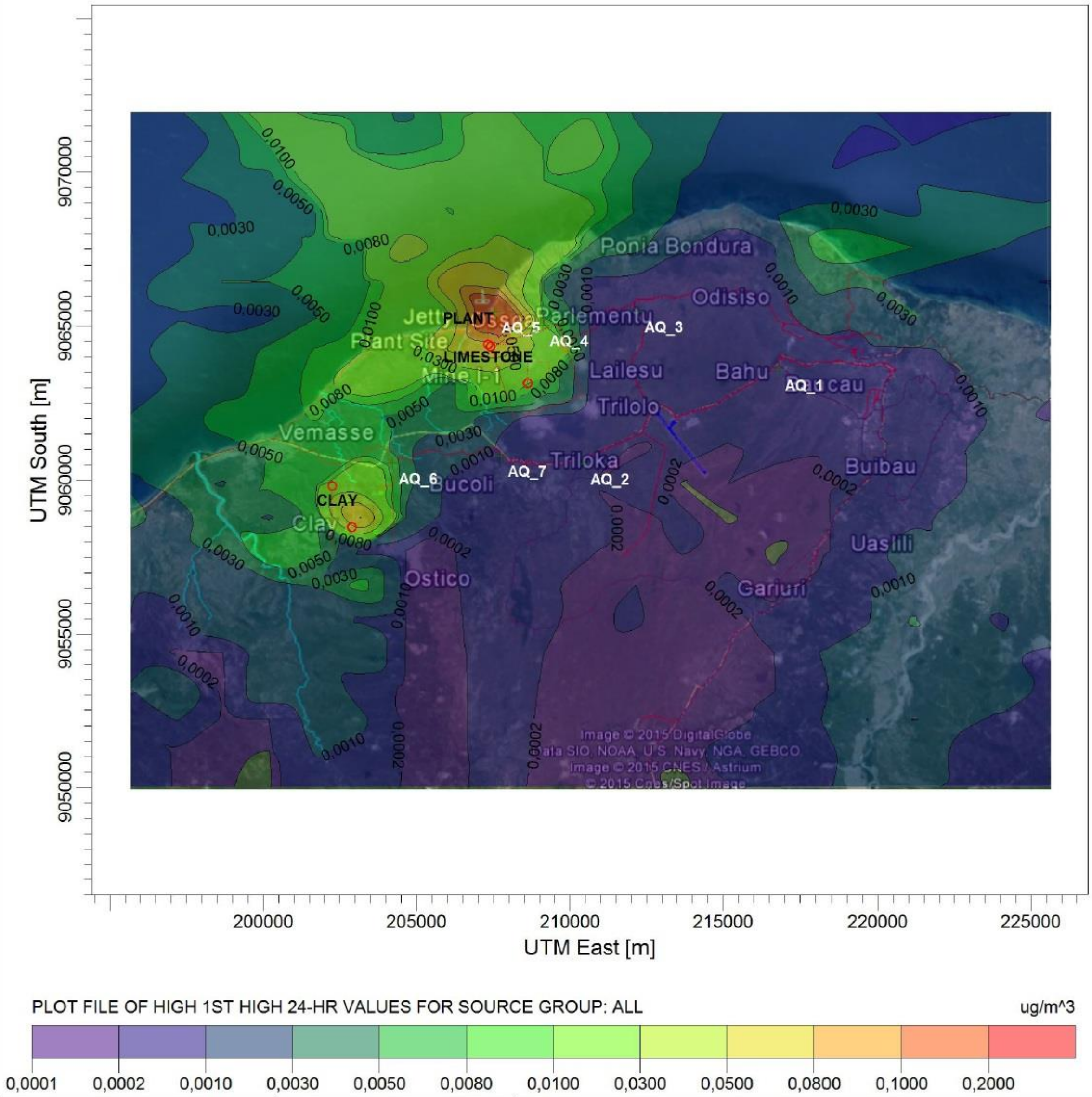
Comments Construction Phase		Company Name **WorleyParsons - Resources and Energy**	
		Modeler **EIA - Air Quality**	WorleyParsons resources & energy
	Output Type **Concentration**	SCALE: 1:194.239 0 — 5 km	
	Maximum Concentration **0,67382 ug/m^3**		

AERMOD View - Lakes Environmental Software

Figure 4.12 SO_2 - 1st High 1 Hour Ambient Concentration (Construction Phase)

Project Title

SO2 - 1st High 24 Hour Ambient Concentration (Construction Phase)



Comments		Company Name	
Construction Phase		**WorleyParsons - Resources and Energy**	
		Modeler **EIA - Air Quality**	WorleyParsons resources & energy
	Output Type **Concentration**	SCALE: 1:203.952 0 — 5 km	
	Maximum Concentration **0,17197 ug/m^3**		

AERMOD View - Lakes Environmental Software

Figure 4.13 SO_2 - 1st High 24 Hour Ambient Concentration (Construction Phase)

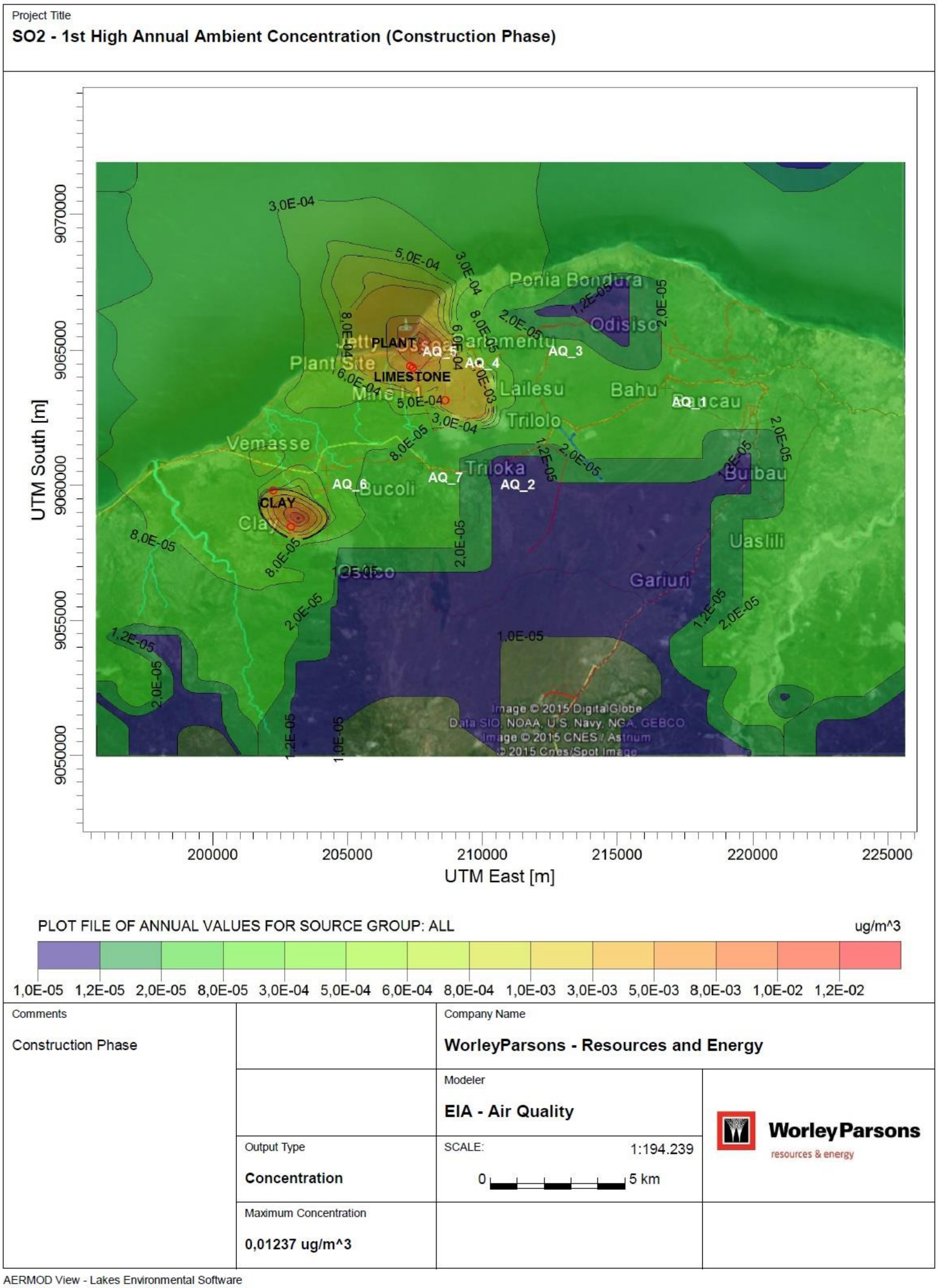
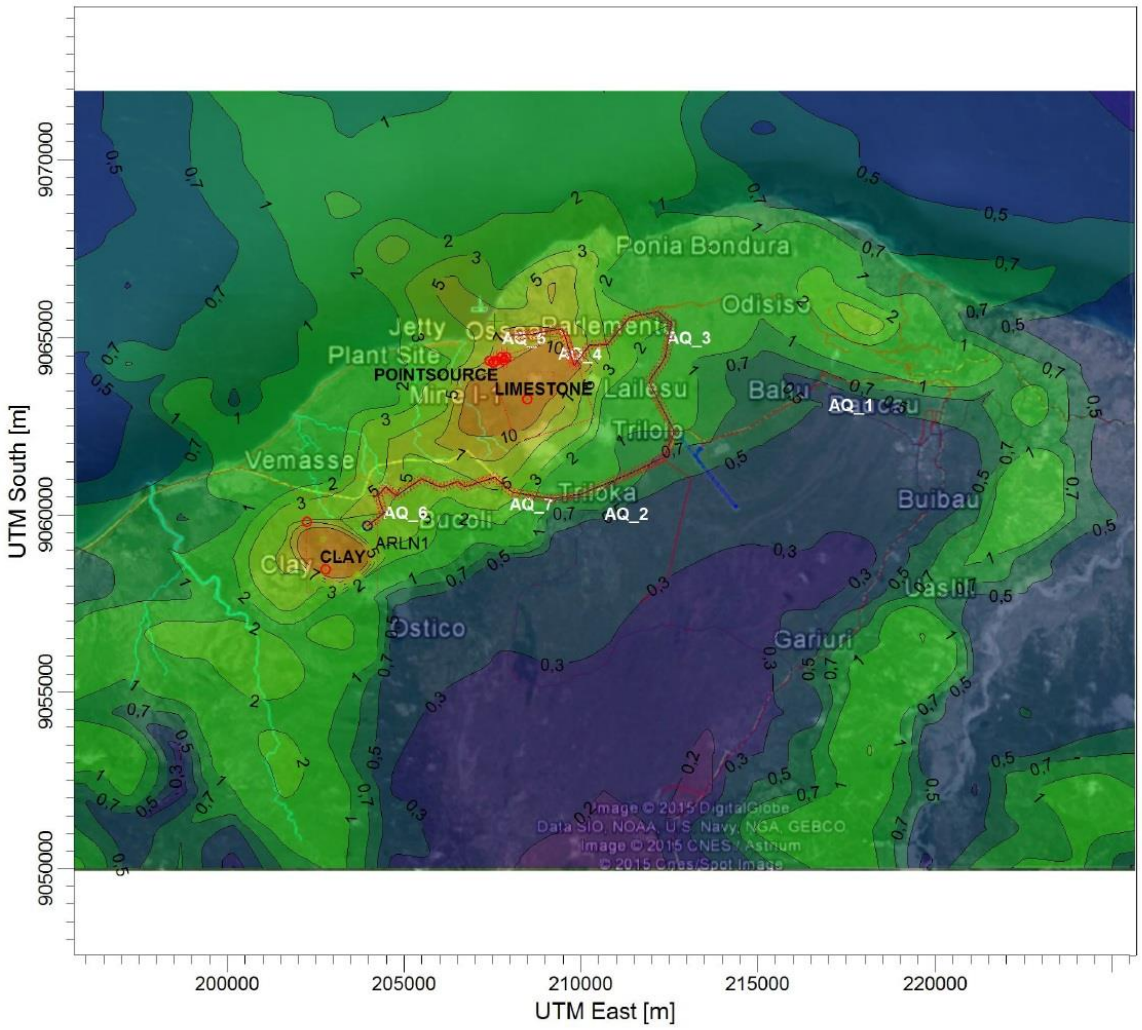


Figure 4.14 SO_2 - 1st High Annual Ambient Concentration (Construction Phase)

Project Title

PM10 - 1st High 24 Hour Ambient Concentration (Operation Phase)



PLOT FILE OF HIGH 1ST HIGH 24-HR VALUES FOR SOURCE GROUP: ALL ug/m^3

0,1 0,2 0,3 0,5 0,7 1,0 2,0 3,0 5,0 7,0 10,0 30,0

Comments Operation Phase		Company Name **WorleyParsons - Resources and Energy**
		Modeler **EIA - Air Quality**
	Output Type **Concentration**	SCALE: 1:188.674 0 5 km
	Maximum Concentration **30,46069 ug/m^3**	

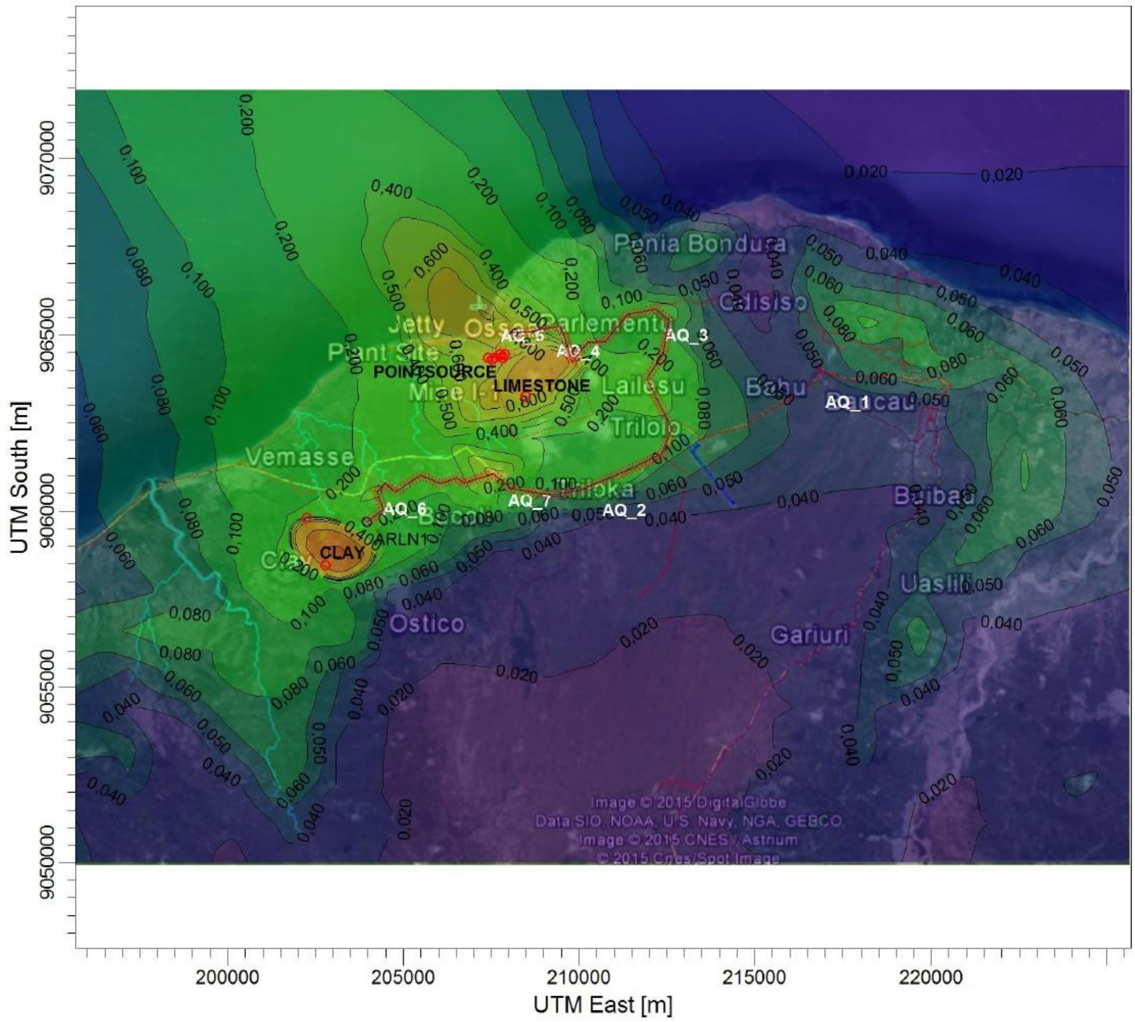
WorleyParsons resources & energy

AERMOD View - Lakes Environmental Software

Figure 4.15 PM_{10} - 1st High 24 Hour Ambient Concentration Operation Phase)

Project Title

PM10 - 1st High Annual Ambient Concentration (Operation Phase)



PLOT FILE OF ANNUAL VALUES FOR SOURCE GROUP: ALL — ug/m^3

0,001 | 0,020 | 0,040 | 0,050 | 0,060 | 0,080 | 0,100 | 0,200 | 0,400 | 0,500 | 0,600 | 0,800 | 1,000 | 2,000 | 4,000 | 5,000

Comments: Operation Phase

Company Name: **WorleyParsons - Resources and Energy**

Modeler: **EIA - Air Quality**

Output Type: **Concentration**

SCALE: 1:188.674 (0 — 5 km)

Maximum Concentration: **4,97258 ug/m^3**

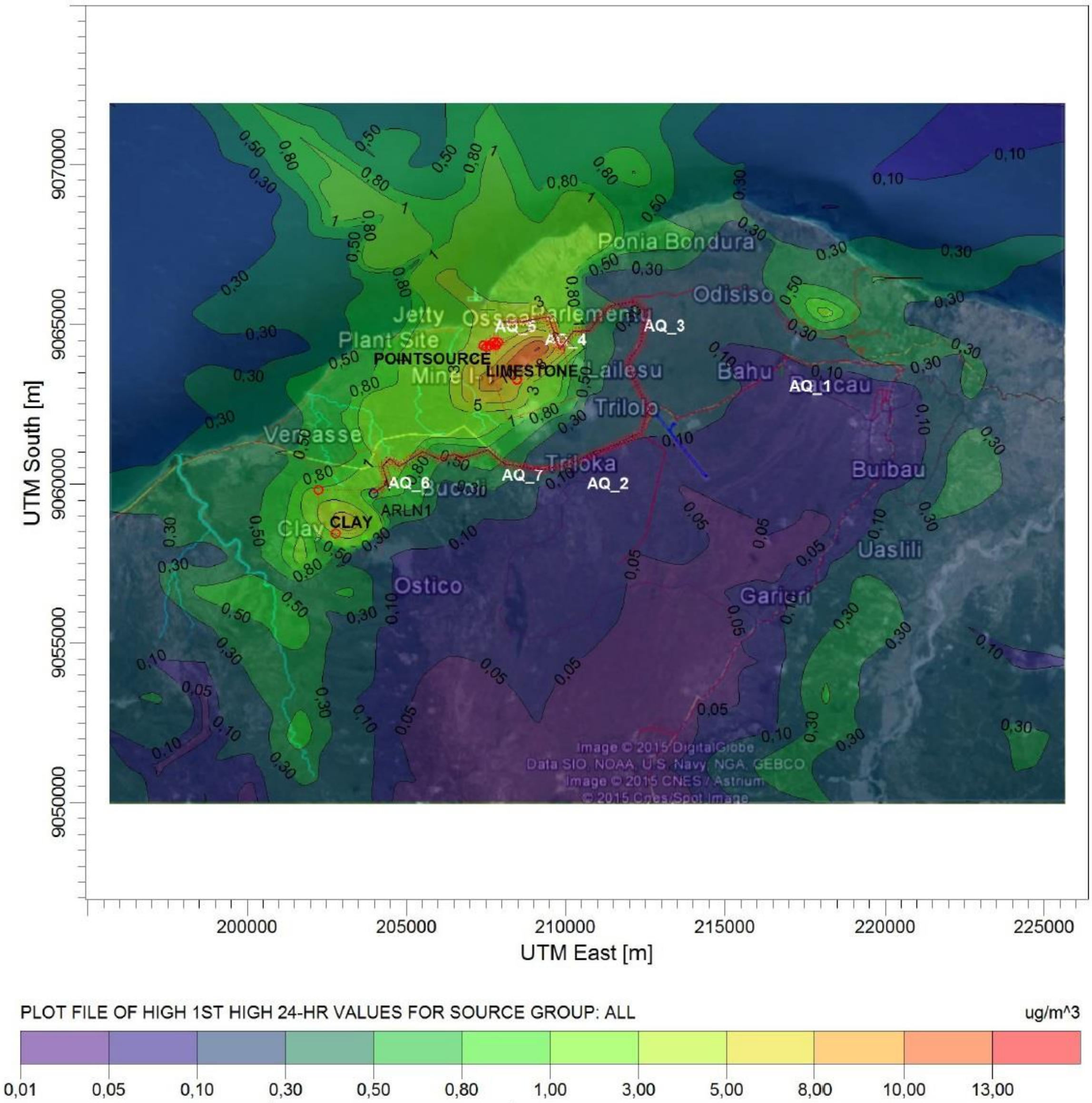
WorleyParsons resources & energy

AERMOD View - Lakes Environmental Software

Figure 4.16 PM_{10} - 1st High Annual Ambient Concentration (Operation Phase)

Project Title

PM2.5 - 1st High 24 Hour Ambient Concentration (Operation Phase)



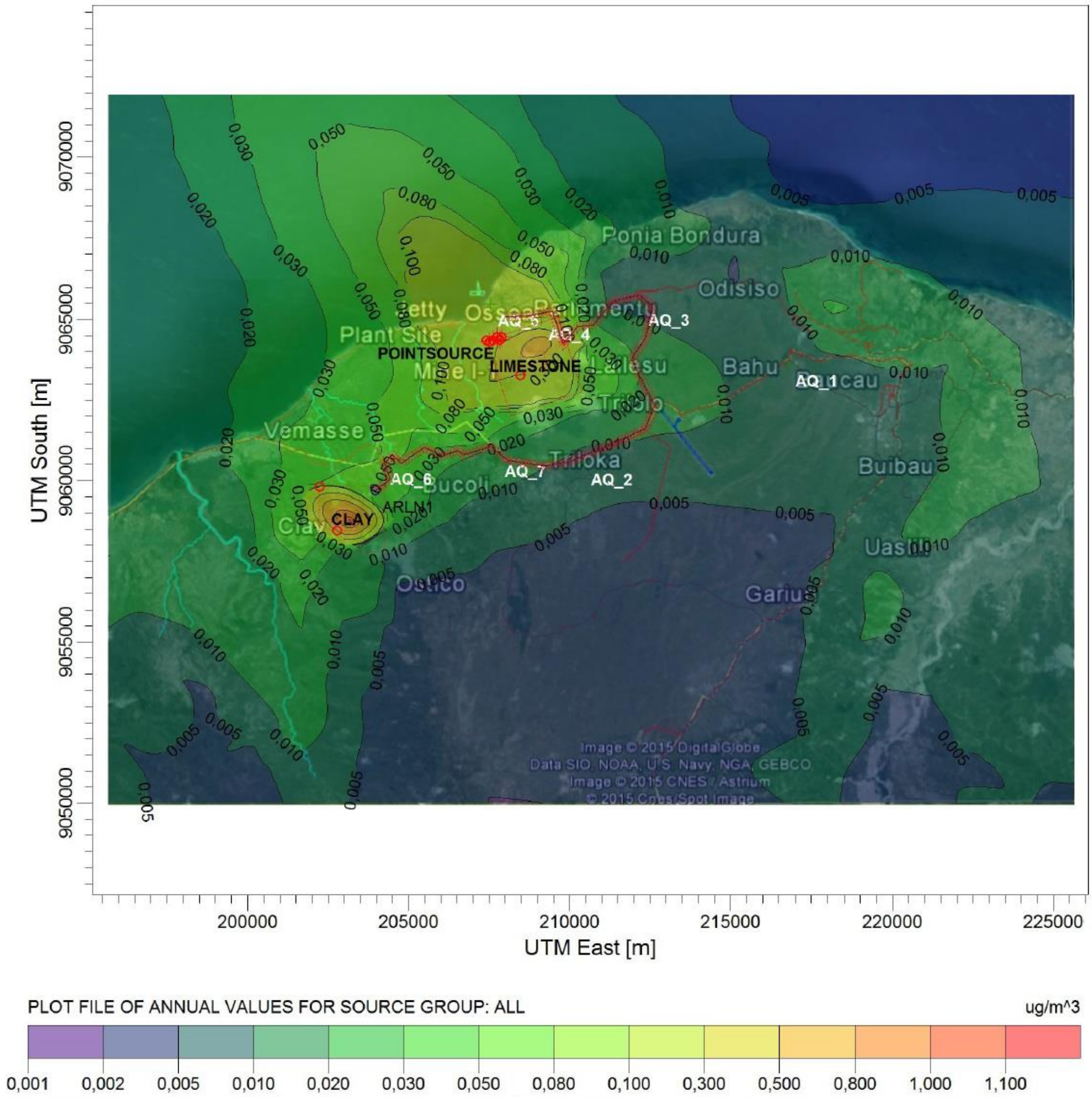
Comments		Company Name	
Operation Phase		**WorleyParsons - Resources and Energy**	
		Modeler **EIA - Air Quality**	WorleyParsons resources & energy
	Output Type **Concentration**	SCALE: 1:197.704 0 — 5 km	
	Maximum Concentration **13,36986 ug/m^3**		

AERMOD View - Lakes Environmental Software

Figure 4.17 $PM_{2.5}$ - 1st High 24 Hour Ambient Concentration (Operation Phase)

Project Title

PM2.5 - 1st High Annual Ambient Concentration (Operation Phase)



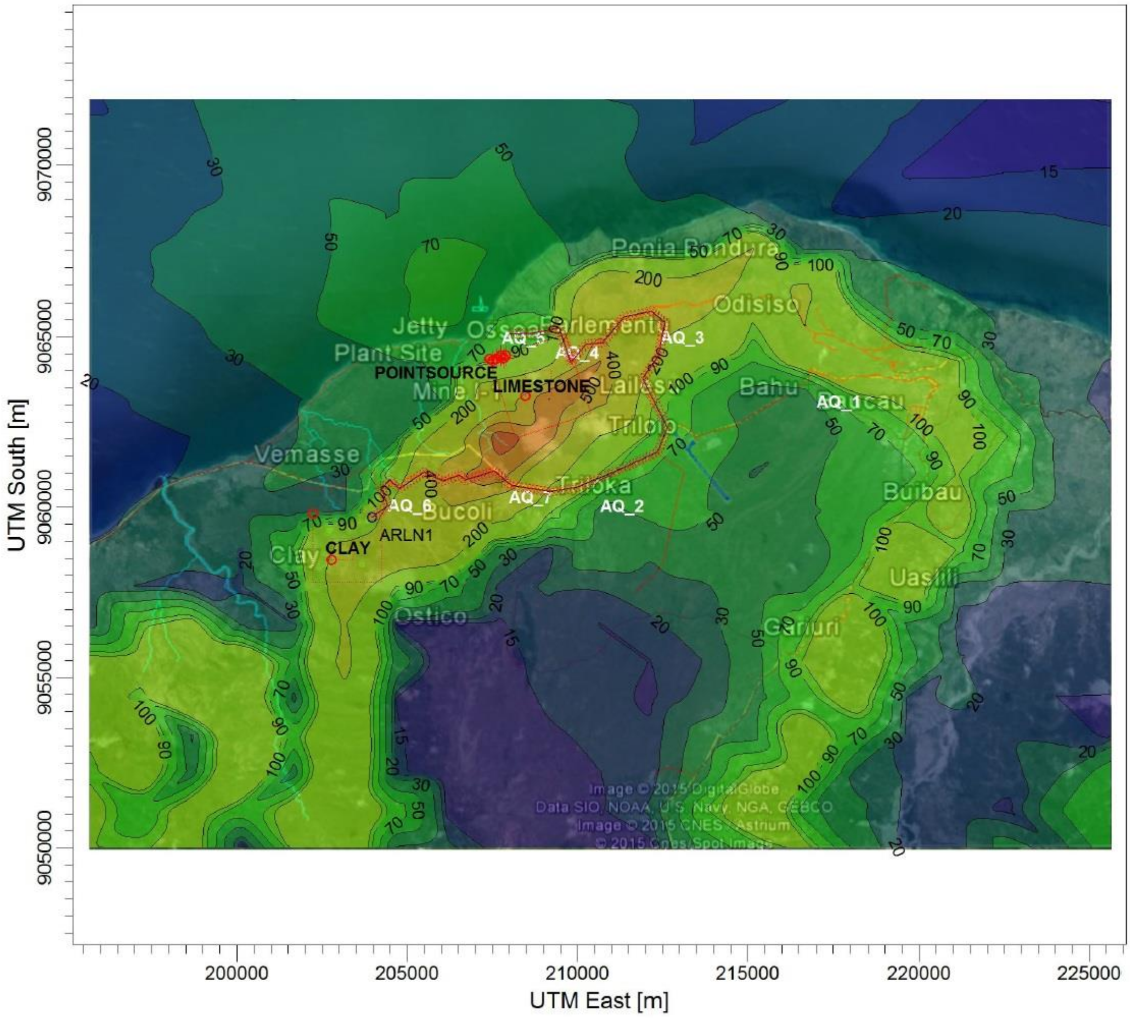
Comments		Company Name	
Operation Phase		**WorleyParsons - Resources and Energy**	
		Modeler **EIA - Air Quality**	WorleyParsons resources & energy
	Output Type **Concentration**	SCALE: 1:194.239 0 — 5 km	
	Maximum Concentration **1,11203 ug/m^3**		

AERMOD View - Lakes Environmental Software

Figure 4.18 $PM_{2.5}$ - 1st High Annual Ambient Concentration (Operation Phase)

Project Title

CO - 1st High 1 Hour Ambient Concentration (Operation Phase)



PLOT FILE OF HIGH 1ST HIGH 1-HR VALUES FOR SOURCE GROUP: ALL — ug/m^3

8 | 10 | 15 | 20 | 30 | 50 | 70 | 90 | 100 | 200 | 400 | 500 | 600 | 659

Comments: Operation Phase

Company Name: **WorleyParsons - Resources and Energy**

Modeler: **EIA - Air Quality**

Output Type: **Concentration**

SCALE: 1:194.239 — 0 … 5 km

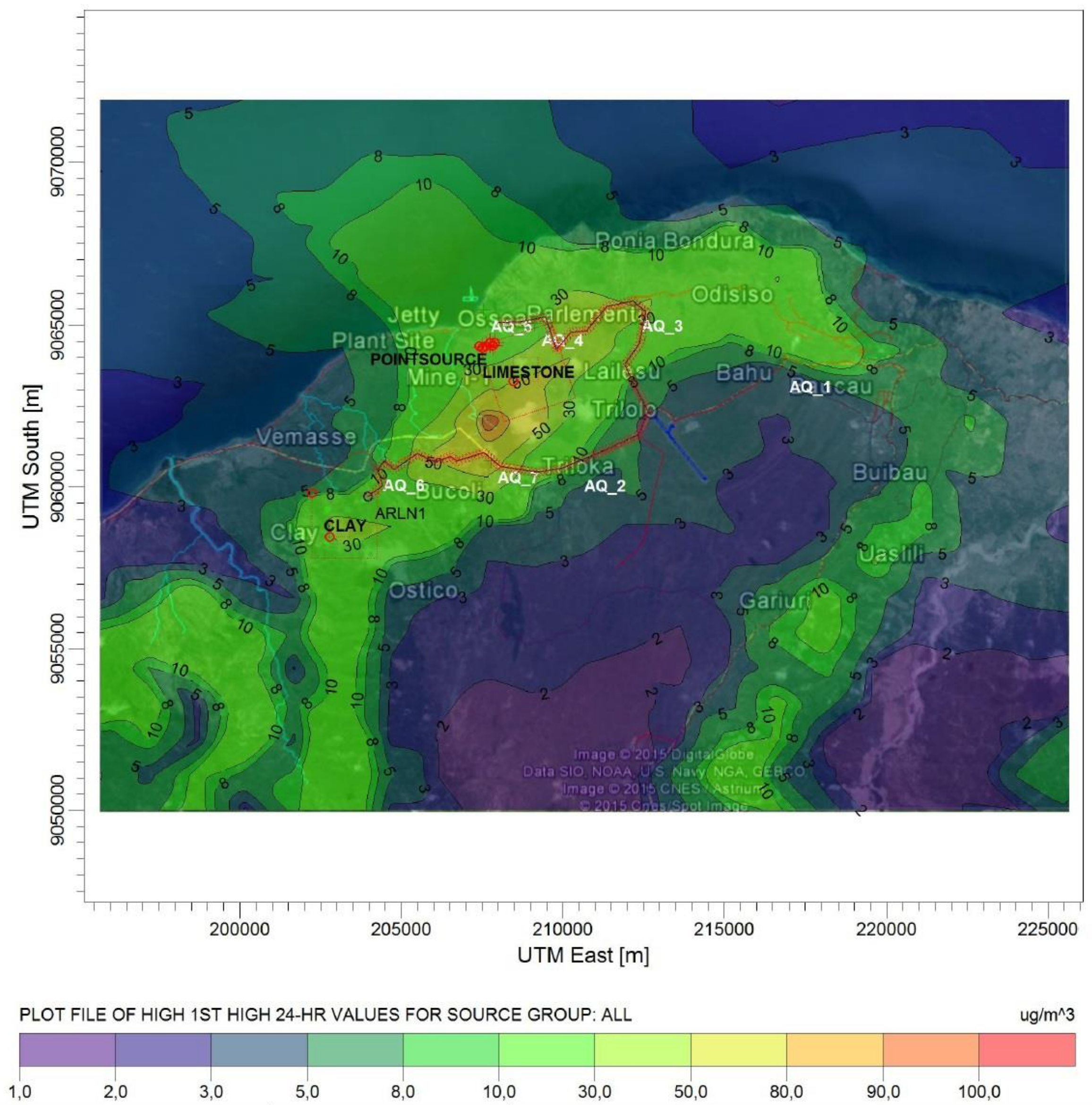
Maximum Concentration: **658,67683 ug/m^3**

AERMOD View - Lakes Environmental Software

Figure 4.19 CO - 1st High 1 Hour Ambient Concentration (Operation Phase)

Project Title

CO - 1st High 24 Hour Ambient Concentration (Operation Phase)



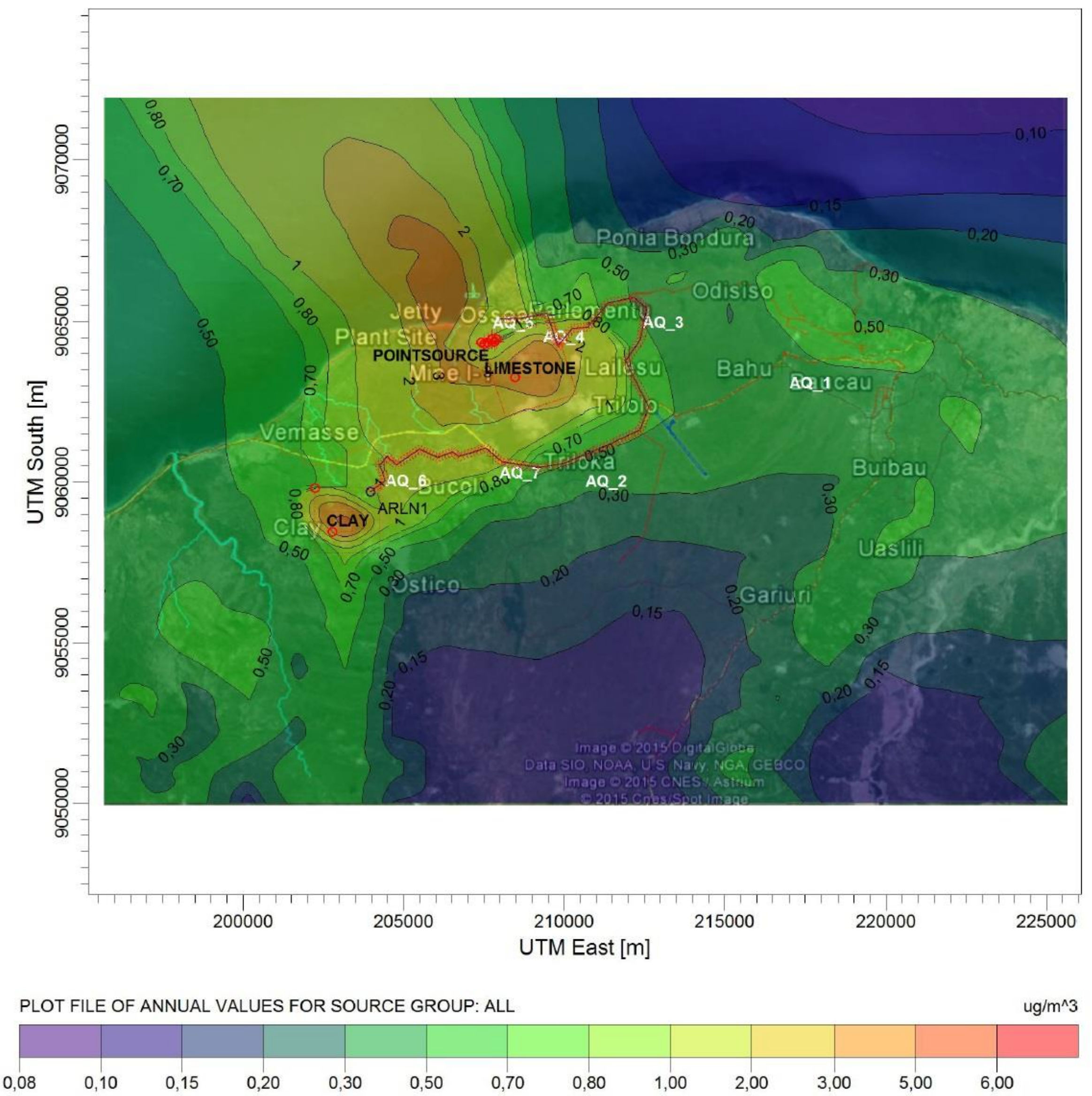
Comments		Company Name	
Operation Phase		WorleyParsons - Resources and Energy	
		Modeler EIA - Air Quality	WorleyParsons resources & energy
	Output Type Concentration	SCALE: 1:194.239 0 — 5 km	
	Maximum Concentration 100,14775 ug/m^3		

AERMOD View - Lakes Environmental Software

Figure 4.20 CO - 1st High 24 Hour Ambient Concentration (Operation Phase)

Project Title

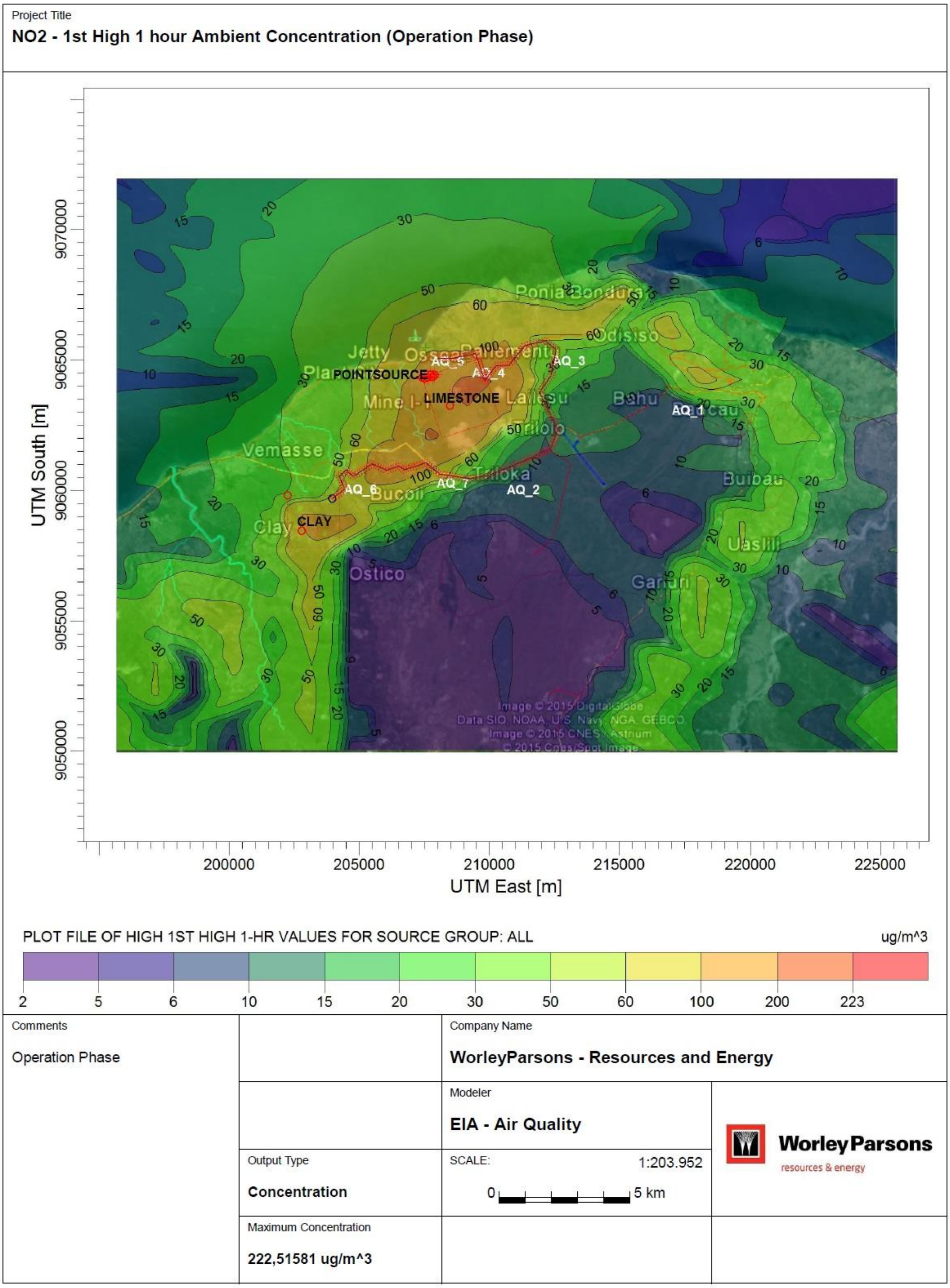
CO - 1st High Annual Ambient Concentration (Operation Phase)



Comments		Company Name	
Operation Phase		**WorleyParsons - Resources and Energy**	
		Modeler **EIA - Air Quality**	WorleyParsons resources & energy
	Output Type **Concentration**	SCALE: 1:194.239 0 — 5 km	
	Maximum Concentration **5,88445 ug/m^3**		

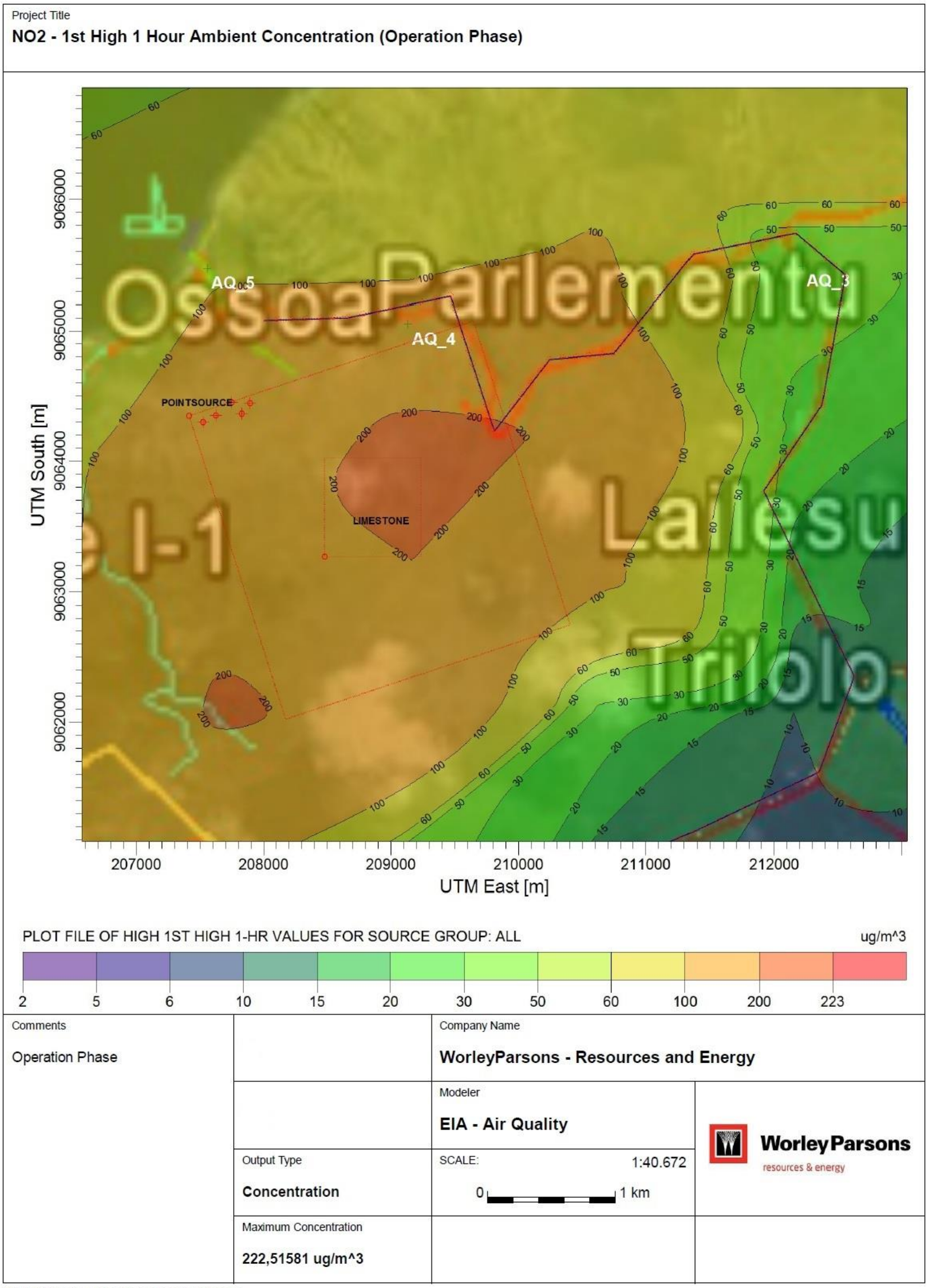
AERMOD View - Lakes Environmental Software

Figure 4.21 CO - 1st High Annual Ambient Concentration (Operation Phase)



AERMOD View - Lakes Environmental Software

Figure 4.22 NO_2 - 1st High 1 Hour Ambient Concentration (Operation Phase)

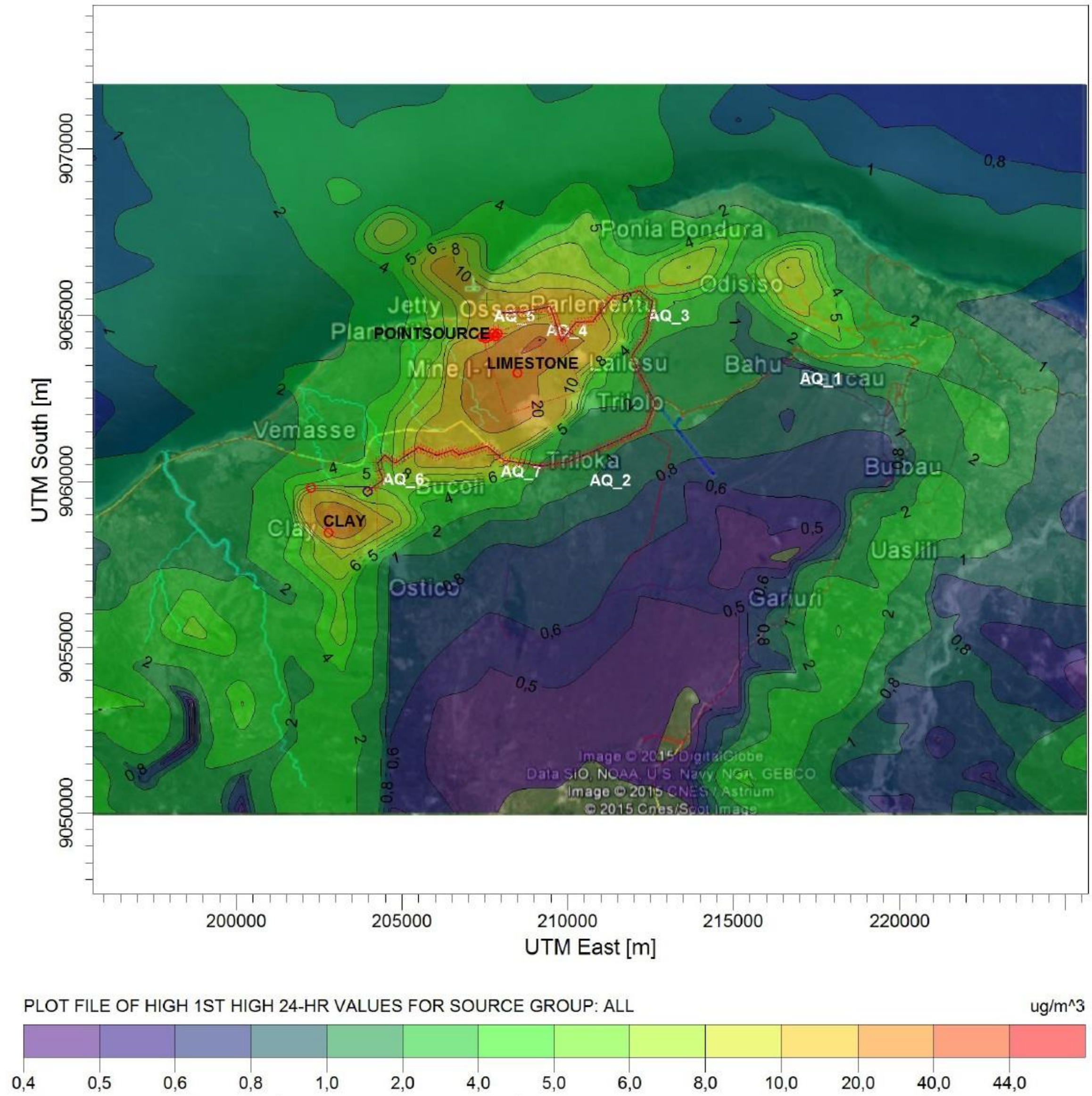


AERMOD View - Lakes Environmental Software

Figure 4.23 NO_2 - 1st High 1 Hour Ambient Concentration – Closer View (Operation Phase)

Project Title

NO2 - 1st High 24 hour Ambient Concentration (Operation Phase)



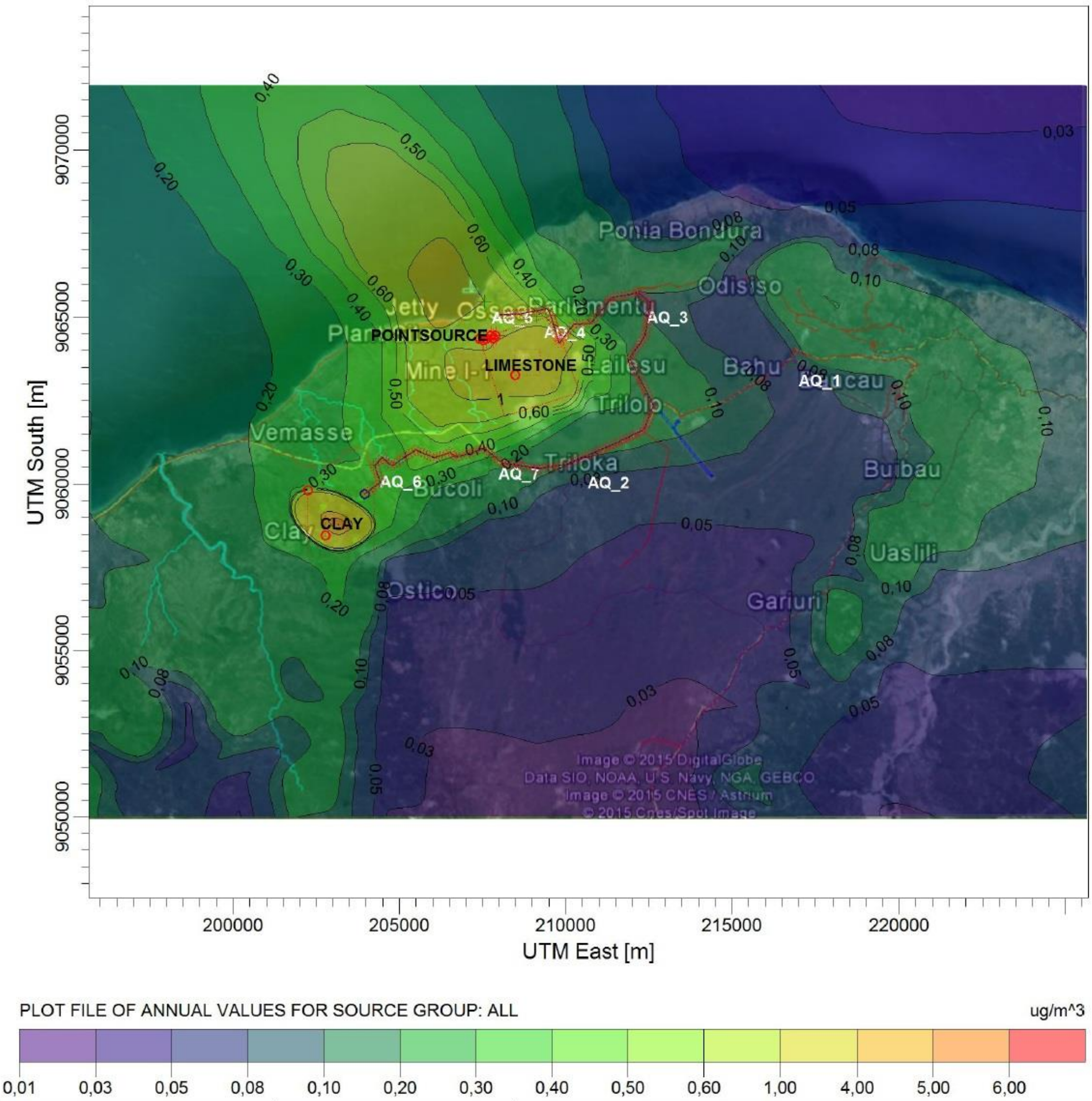
Comments Operation Phase		Company Name **WorleyParsons - Resources and Energy**	
		Modeler **EIA - Air Quality**	WorleyParsons resources & energy
	Output Type **Concentration**	SCALE: 1:188.674 0 ─ 5 km	
	Maximum Concentration **44,22981 ug/m^3**		

AERMOD View - Lakes Environmental Software

Figure 4.24 NO_2 - 1st High 24 Hour Ambient Concentration (Operation Phase)

Project Title

NO2 - 1st High Annual Ambient Concentration (Operation Phase)



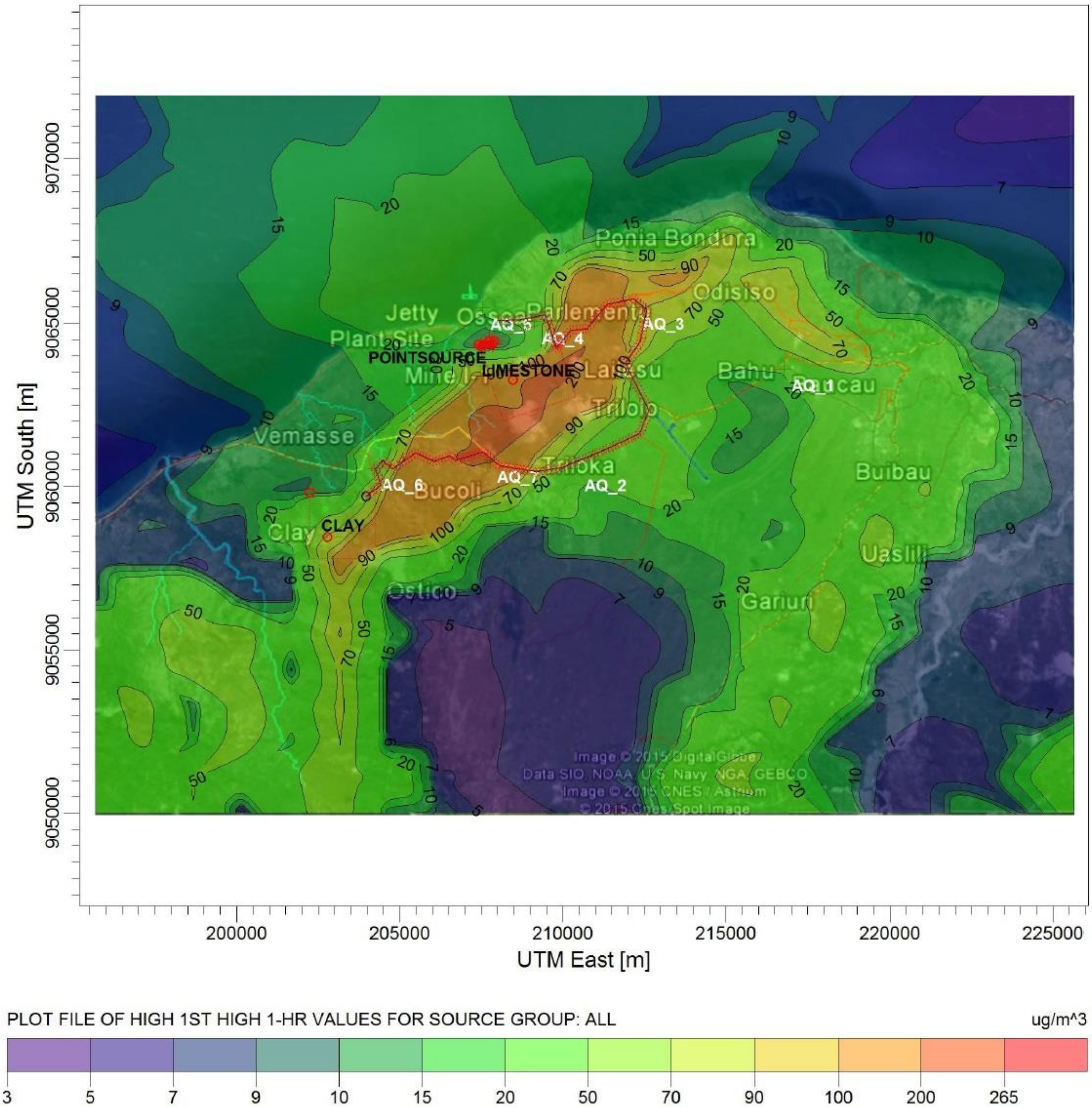
Comments		Company Name	
Operation Phase		WorleyParsons - Resources and Energy	
		Modeler EIA - Air Quality	WorleyParsons resources & energy
	Output Type Concentration	SCALE: 1:188.674 0 — 5 km	
	Maximum Concentration 6,07035 ug/m^3		

AERMOD View - Lakes Environmental Software

Figure 4.25 NO_2 - 1st High Annual Ambient Concentration (Operation Phase)

Project Title

SO2- 1st High 1 Hour Ambient Concentration (Operation Phase)



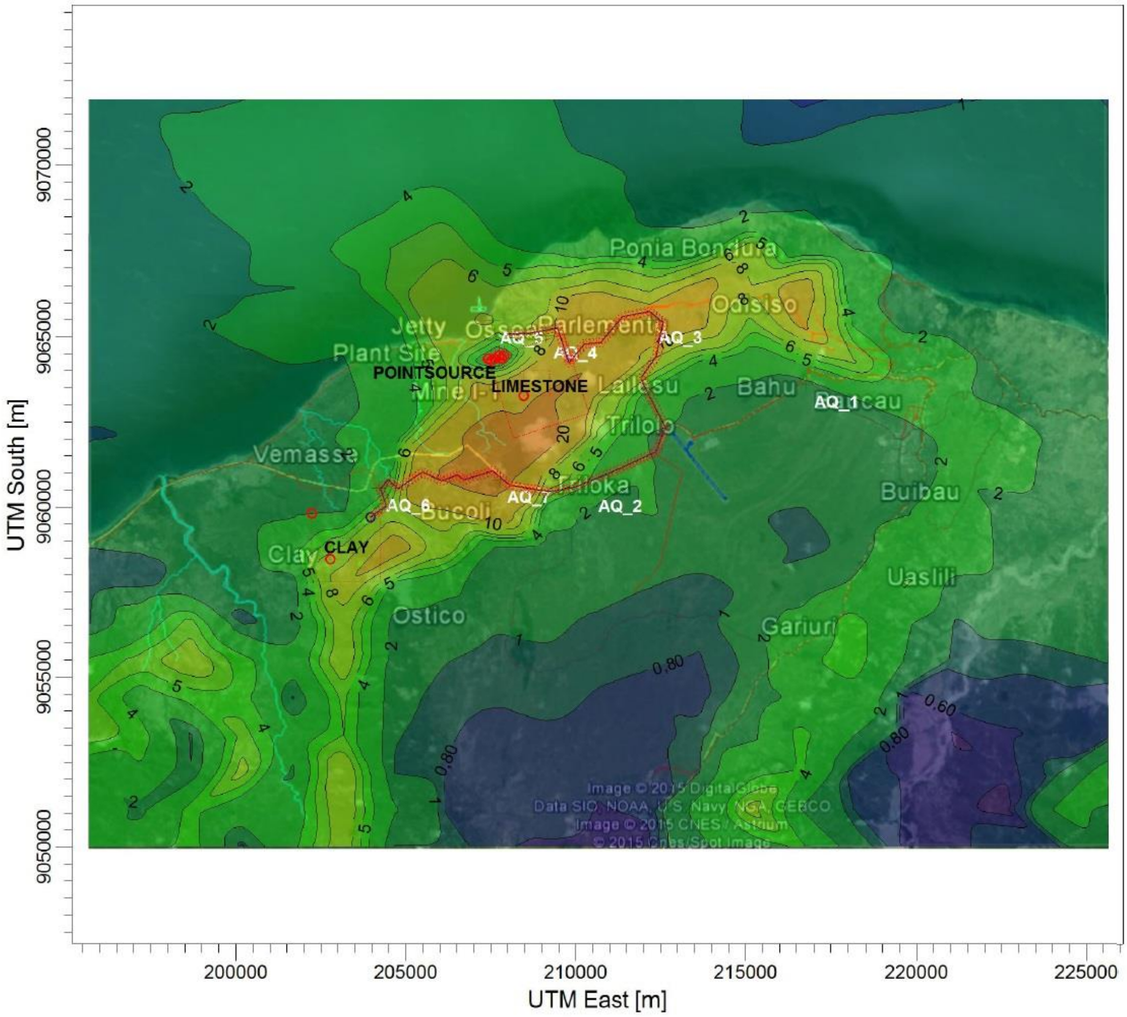
Comments		Company Name	
Operation Phase		WorleyParsons - Resources and Energy	
		Modeler: EIA - Air Quality	WorleyParsons resources & energy
	Output Type: Concentration	SCALE: 1:194.239 (0 — 5 km)	
	Maximum Concentration: 263,47893 ug/m^3		

AERMOD View - Lakes Environmental Software

Figure 4.26 SO_2 - 1st High 1 Hour Ambient Concentration (Operation Phase)

Project Title

SO2- 1st High 24 Hour Ambient Concentration (Operation Phase)



PLOT FILE OF HIGH 1ST HIGH 24-HR VALUES FOR SOURCE GROUP: ALL — ug/m^3

0,40 | 0,50 | 0,60 | 0,80 | 1,00 | 2,00 | 4,00 | 5,00 | 6,00 | 8,00 | 10,00 | 20,00 | 40,00

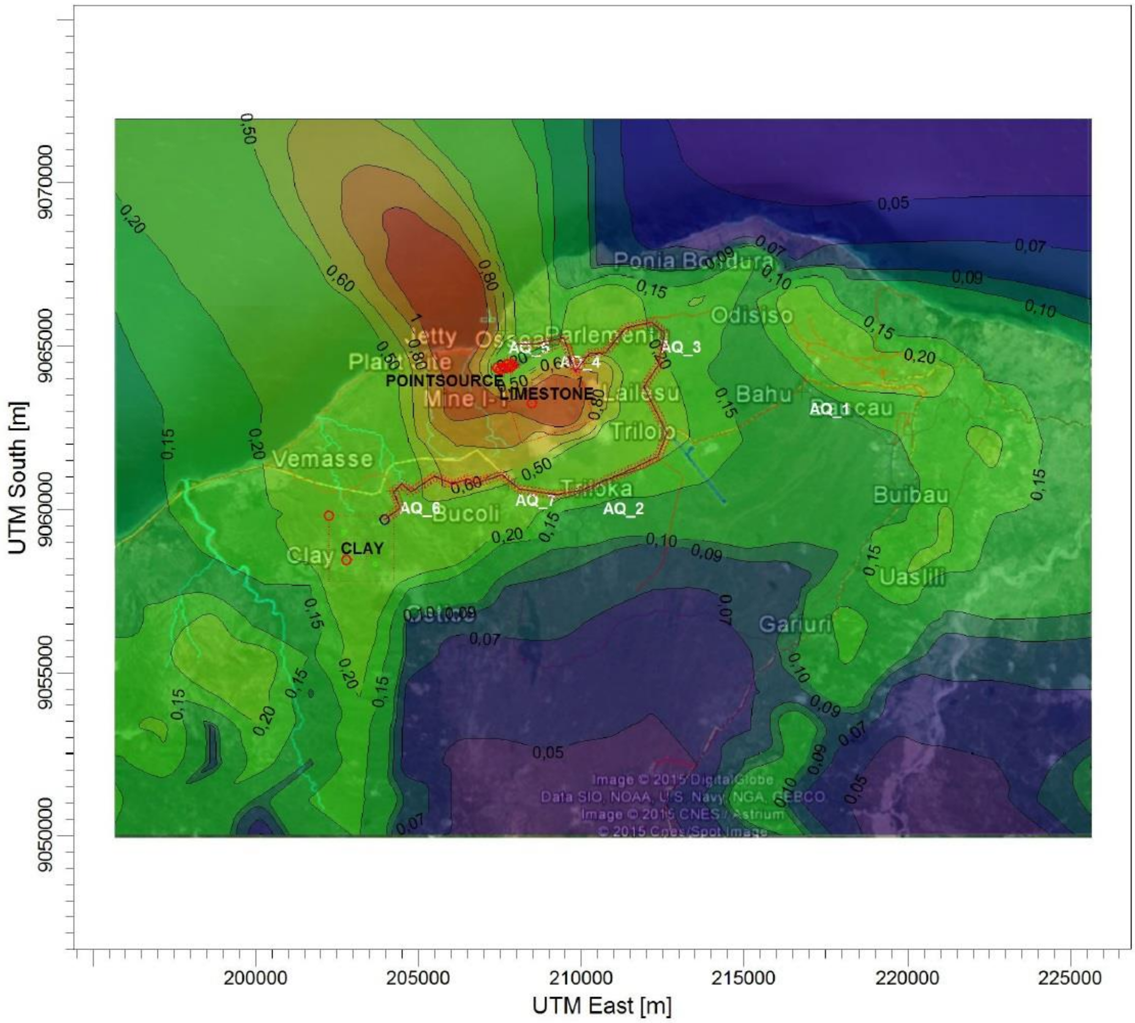
Comments		Company Name	
Operation Phase		**WorleyParsons - Resources and Energy**	
		Modeler: **EIA - Air Quality**	WorleyParsons resources & energy
	Output Type: **Concentration**	SCALE: 1:194.239 (0 — 5 km)	
	Maximum Concentration: **40,03219 ug/m^3**		

AERMOD View - Lakes Environmental Software

Figure 4.27 SO_2 - 1st High 24 Hour Ambient Concentration (Operation Phase)

Project Title

SO2- 1st High Annual Ambient Concentration (Operation Phase)



PLOT FILE OF ANNUAL VALUES FOR SOURCE GROUP: ALL ug/m^3

0,03 0,05 0,07 0,09 0,10 0,15 0,20 0,50 0,60 0,80 1,00 1,66

Comments Operation Phase		Company Name **WorleyParsons - Resources and Energy**	
		Modeler **EIA - Air Quality**	WorleyParsons resources & energy
	Output Type **Concentration**	SCALE: 1:203.952 0 5 km	
	Maximum Concentration **1,65708 ug/m^3**		

AERMOD View - Lakes Environmental Software

Figure 4.28 SO_2 - 1st High Annual Ambient Concentration (Operation Phase)

4.2.3 Summary of the Modelling Output

The summary of predicted 1st high concentration for each pollutant is presented in **Table 4.17** for construction phase and **Table 4.18** for operation phase**.** The 1st high concentration is the highest concentration which occurs in each receptor for certain averaging time. During the construction phase, the highest concentration might occur less than 500 m away from the construction activities. During the operation phase, the highest concentrations generally occur farther at 1 up to 3 km away from the main sources (such as stacks). Although these highest concentrations are below the standards, people will undergo results of dispersion for a very long time (as long as the operation phase of the project), therefore mitigation measures during the construction and operation phase must be properly applied.

The dispersion patterns are presented by isopleth map as shown in **Figure 4.2** until **Figure 4.28.** In general, in can be concluded that highest concentrations are located in the mining area, cement plant and jetty area. Pollutants tend to disperse to the North West direction from the sources, in the opposite direction from where the prevailing winds blow (prevailing winds blow mostly from south east direction). Moreover, the area located in the south east direction from the sources (plant and mining area) has a higher level, which is capable of preventing pollutant dispersion by topographic barrier.

During the construction phase, predicted ambient concentration for all averaging time and all air pollutant parameters are below the ambient standard. While during operation phase, predicted ambient concentration for PM_{10}-$PM_{2.5}$ (24 hour and annual averaging time), CO-SO_2 (1 hour, 24 hour, and annual averaging time) and NO_2 (annual averaging time) are also below the ambient standard. Only 1 hour NO_2 concentrations (highest concentration: 222 µg/Nm^3) are predicted to be slightly above the standard (200 µg/Nm^3 according to WHO standard), with occurrence frequency shown in **Table 4.19**. Total number of 1 hour NO_2 calculated data are 3,924,480 data (derived from 448 receptors x 8760 hour in a year), and total number of exceedance (data above ambient standard) are 25 data only, therefore the exceedance percentage is only 0.0006%. The location which will undergo probable exceedance is located inside the limestone mining area, and shall not reach the sensitive receptor in AQ4 (illustrated in **Figure 4.23**). The 1 hour NO_2 concentration in AQ4 is predicted to be 100 to 150 µg/Nm^3.

The dispersed pollutants are predicted to be able to reach the sensitive areas, but the concentration level reaching these areas are all below the standard for each averaging time. Sensitive receptors which may experience higher dispersed concentration than other receptors are located in:

- AQ5, around the jetty plant area, scattered small cluster of fisherman village close to the plant area.
- AQ4, Aldeia Osso-ua, settlement close to the plant area.
- AQ6 Wailacama, settlement area at north east of clay quarry.

5. MITIGATION

The cement plant project will have negative impacts to the air quality, not only during construction phase but also during operation phase. Direct impact is indicated by the increase of certain air pollutant in the ambient air, caused by emission of significant amount of air pollutants due to air pollutant generating activities. Although the impact assessment using modelling tool has shown that the future ambient concentration generally below the ambient standard, mitigation must be implemented to keep the concentration of air pollutants in the ambient air is in allowable level.

5.1 Mitigation during Construction Phase

A relative high concentration of particulates will be emitted to the ambient air, therefore the mitigation should include, but not limited to the followings:

General Mitigation

- Ensuring that all adequate dust control measures are implemented in a timely manner during all phases of construction development.
- For all sites with areas of open ground that are close to sensitive receptors, construction works should follow best practice to prevent dust and other pollutant emissions from being carried outside the boundary;
- Provide a control zone around the site boundary to protect sensitive receptors (this could include an area of hard-standing, or by erecting effective barriers around dusty activities or the site boundary);
- Machinery, fuel and chemical storage and dust generating activities should not be located close to boundaries and sensitive receptors if at all possible.
- All workers onsite will undertake environmental awareness training to highlight potential issues specific to this construction project.
- The contractor will provide the need based safety measures by providing personal protective equipment (PPE) to the workers based on the nature of the work e.g., providing helmets and goggles for the workers working with the installation of roofs, providing ear plugs or ear muff for workers who works using power machinery, ear protection will help protect the important sense of hearing.
- Ensure correct working methods are employed during construction process to avoid.

Mitigation during Site Preparation

Site preparation related to earth moving works. Excavation and earthwork activities can be a potential source of dust outside the site if they are not properly controlled;

- All material excavated, stockpiled, or graded shall be sufficiently watered, treated, or covered to prevent fugitive dust from leaving the property boundaries and causing a public nuisance or a violation of an ambient air standard.
- Watering should occur at least twice daily, with complete site coverage.
- All land clearing, grading, earth moving, or excavation activities on a project should be suspended as necessary to prevent excessive windblown dust when winds are expected to exceed 20 mph.
- All areas with vehicle traffic shall be watered or have dust palliative applied as necessary for regular stabilization of dust emissions.

- All on-site vehicle traffic shall be limited to a speed of 15 mph on unpaved roads.
- All material transported off-site shall be either sufficiently watered or securely covered to prevent public nuisance, and there must be a minimum of six (6) inches of freeboard in the bed of the transport vehicle.

Mitigation during Construction of Facilities

Construction works should carry out the following controls to reduce particulates and gases associated with vehicles - such as that from exhaust emissions, the contact of tires on the road surface or dust blowing from materials carried.

- ***Vehicle operation***
  - No vehicles or plant will be left idling unnecessarily;
  - Reduce the number of vehicle movements through better planning;
  - Set an appropriate speed limit on haul routes;
  - Clearly label all vehicles associated with the contract.
- ***Vehicle certification***
  - All heavy duty vehicles should meet certain emission regulation from local Environmental Protection Agency.
- ***Emission abatement***
  - Use a good quality of fuel (e.g. with low sulphur content)
  - Engines and exhaust systems should be regularly serviced according to manufacturer's recommendations and maintained to meet statutory limits/opacity tests.

  Construction works also use heavy equipment which can emit pollutants from internal combustion of fuel in their machines. The followings should prevent the emissions:

  - All heavy equipment should meet certain emission regulation from local Environmental Protection Agency.
  - Equipment should not be left idling unnecessarily.
  - Non Road Mobile Machinery (vehicles and plant) should be well maintained. Should any emissions of dark smoke occur (except during start up) then the relevant machinery should be stopped immediately and any problem rectified before being used.

Mitigation Monitoring and Reporting

A mitigation monitoring and reporting program should be developed and should include the following components:

- Monitor the air quality in sensitive receptors, especially AQ5 (representing the construction area), AQ4 (settlement area in Aldeia Osso-ua), AQ6 (settlement area in Wailacama), once every six month to ensure the air quality parameters do not violate the standard. Parameters which should be measured area:
  - PM_{10}, $PM_{2.5}$, CO, NO_2, and SO_2 : representing the primary air pollutant.
  - Ozone: representing the secondary air pollutant.

- Monitoring results and mitigation activities should be reported to the local environmental agency

5.2 Mitigation during Operation Phase

The main sources of dust from the cement production process are kilns, raw materials mills, clinker coolers, and cement mills. In all these processes, large volumes of gases flow through dusty material.

Cement manufacturing involves the movement of dusty or pulverized materials from quarrying the limestone to loading the finished product for shipment, and fugitive dust emissions can arise during the storage and handling of materials and solid fuels, and also from road surfaces. Particulate releases from the packing and dispatch of clinker/cement can also be significant.

Mitigation in Cement Plant Area

Emission from stacks due to activities in crusher, raw mill, coal mill, clinker cooler, cement mill, packing plant, should use the following mitigation measures:

Related to Stack's Emission

- Ensure maximum efficiency of combustion in kiln.
- Performance guarantee of suitably designed Bag filters/ ESP will limit the dust concentration to 30 mg/ Nm^3 in all emissions.
- In the event of failure of any pollution control equipment, automatic tripping in the control system should be provided.
- Efficiency of each air pollution control equipment will be ensured to more than 99%.
- Continuous dust monitor should be installed on kiln stack.
- Performance guarantee of SO_2, NO_x, and CO emissions from stacks is within the norms of 200 mg/ Nm^3, 800 mg/ Nm^3, and 500 mg/ Nm^3 respectively as specified.
- A well-designed low NO_x burner system will limit the core flame temperature to ensure a low value of NO_x.
- Regular preventive maintenance of pollution control equipment.
- All vehicles and their exhausts will be well maintained and regularly tested for emission concentration.

Related to fugitive emission

- Drop distances will be minimized by adjusting the conveyors.
- Dust suppression system by water sprinkler at dump hopper of raw materials.
- Regular dust suppression on the haul roads.
- Plant roads & approach roads will be made of bitumen/ concrete & mechanical vacuum cleaner shall be used for cleaning of dust on internal roads.
- Open areas within the plant premises/ along boundaries of the plant premises will be covered under green belt.
- Raw Materials/ products will be fully covered during transportation to/ from the site by road.

Mitigation in Mining Area

The following corrective measures are proposed for prevention of pollution of air and to maintain it well within the prescribed limits, in the limestone and clay mining area:

- Water spray on haulage roads shall be continuous process & proper maintenance of haul roads shall be done.
- Dust suppression systems (water spraying) will be adopted at faces/ sites before and after blasting and while loading.
- Dust generated due to blast hole drilling will be suppressed by using water injecting system of dust collectors, Proper maintenance of vehicles shall be done to limit gaseous emissions.
- A speed limit will be defined for the trucks/ dumpers moving within the mining area.
- Use of sharp drill bits for drilling holes and drills with water flushing systems (wet drilling) to reduce dust generation
- Mitigation measures for blasting in limestone mine:
    - All blasting will be done by a person who holds license
    - Blasting will be conducted in a manner that prevents injury to persons and damage to public or private property outside the project area
    - Timing of blasting will avoid high wind speeds and when workers are away from the mining face (for example: lunchtime).

Mitigation for Workers

- All workers onsite will undertake environmental awareness training to highlight potential issues specific to this operation project.
- The contractor will provide the need based safety measures by providing personal protective equipment (PPE) to the workers based on the nature of the work.

  Ensure correct working methods are employed during operation process.

Mitigation Monitoring and Reporting

A mitigation monitoring and reporting program should also be developed in operation phase, and should include the following components:

- Monitor the ambient air quality in sensitive receptors: AQ1 (settlement area in Bahu, east-south east of cement plant), AQ3 (School area in Aldeia Parlemento, east of cement plant and north east of limestone mine) AQ4 (settlement area in Aldeia Osso-ua), AQ6 (settlement area in Wailacama, north east of clay quarry) every six month to ensure the air quality parameters do not violate the standard. Parameters which should be measured are:
    - PM_{10}, $PM_{2.5}$, CO, NO_2, and SO_2 : representing the primary air pollutant
    - Ozone: representing the secondary air pollutant
- Monitoring the emission from stacks every six month:
    - Kiln stack and Thermal power plant stack; measured parameters are: particulates (PM_{10}, $PM_{2.5}$), CO, SO_2, and NO_2.

- Cooler ESP stack, cement mill bag house stack, coal mill bag house stack; measured parameter is only particulate (PM_{10},and $PM_{2.5}$).
- Analysing data from CEMS (Continuous Emission Monitoring Systems) installed in Kiln Stack.

- Monitoring results and mitigation activities should be reported to the local environmental agency

6. REFFERENCE

1). EMEP/EEA emission inventory guidebook 2013, section 2.A. 1 Cement Production World Health Organization

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4). Standard Test Method for Nitrogen Dioxide Content of the Atmosphere (Reaction). Active Standard ASTM D1607 | Developed by Subcommittee: D22.03, Book of Standards Volume: 11.07

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APPENDIX

Technical Manual for Modelling of Air Quality using AERMOD

AERMOD is a regulatory steady-state plume modelling system with three separate components: AERMET (AERMOD Meteorological Pre-processor), AERMAP (AERMOD Terrain Pre-processor), and AERMOD (AERMIC Dispersion Model). The AERMOD model includes a wide range of options for modelling air quality impacts of pollution sources, making it a popular choice among the modelling community for a variety of applications.

Figure 1 shows the flow and processing of information in AERMOD. The modelling system consists of one main program (AERMOD) and two pre-processors (AERMET and AERMAP). The major purpose of AERMET is to calculate boundary layer parameters for use by AERMOD. The meteorological INTERFACE, internal to AERMOD, uses these parameters to generate profiles of the needed meteorological variables. In addition, AERMET passes all meteorological observations to AERMOD.

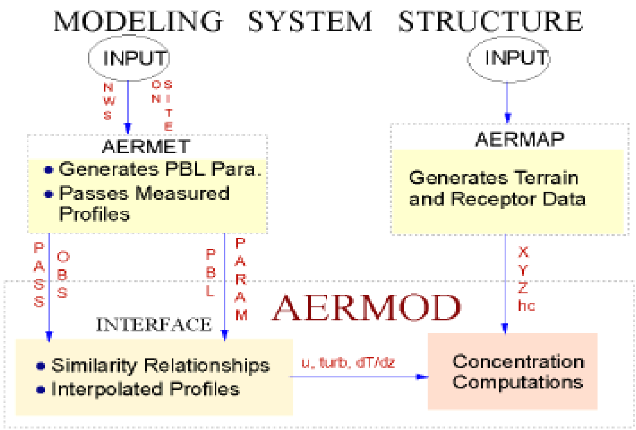


Figure 1 Data Flow in the AERMOD Modelling System

AERMOD Meteorological Processor (AERMET)

One of the major improvements that AERMOD brings to applied dispersion modelling is its ability to characterize the Planetary Boundary Layer (PBL)[2] through both surface and mixed layer scaling. AERMOD constructs vertical profiles of required meteorological variables based on measurements and extrapolations of those measurements using similarity (scaling) relationships. Vertical profiles of wind speed, wind direction, turbulence, temperature, and temperature gradient are estimated using available meteorological observations. The AERMET program is a meteorological pre-processor which prepares hourly surface data and upper air data for use in the AERMOD short-term air quality dispersion model. AERMET was designed to allow for future enhancements to process other types of data and to compute boundary layer parameters with different algorithms. AERMET processes meteorological data in three stages and from this process two files are generated for use with the AERMOD model (see **Figure 2**):

1. A Surface File of hourly boundary layer parameters estimates;
2. A Profile File of multiple-level observations of wind speed, wind direction, temperature, and standard deviation of the fluctuating wind components.

[2] Planetary Boundary Layer (PBL) or Atmospheric Boundary Layer: the bottom layer of the troposphere that is in contact with the surface of the earth.

Flow sheet depicting the AERMET processing stages is shown below.

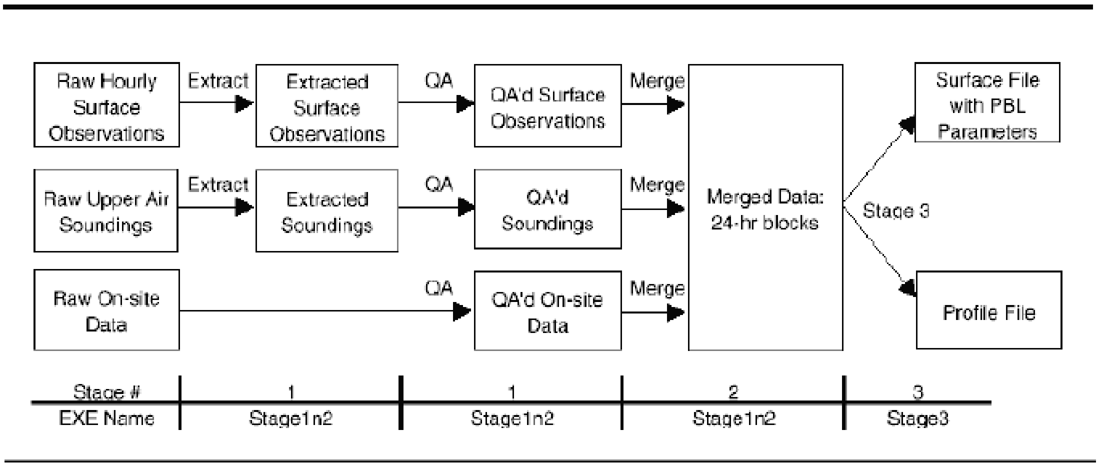


Figure 2 AERMET Processing Stages
(Source: U.S. EPA User's Guide for AERMET – DRAFT)

Surface characteristics in the form of albedo[3], surface roughness and Bowen ratio[4], plus standard meteorological observations (wind speed, wind direction, temperature, and cloud cover), are input to AERMET. AERMET then calculates the PBL parameters (see **Figure 3**): friction velocity (u_*), Monin-Obukhov length (L), convective velocity scale (w_*), temperature scale (θ_*), mixing height (z_i), and surface heat flux (H). These parameters are then passed to the INTERFACE (which is within AERMOD) where similarity expressions (in conjunction with measurements) are used to calculate vertical profiles of wind speed (u), lateral and vertical turbulent fluctuations (σ_v, σ_w), potential temperature gradient ($d\theta/dz$), and potential temperature (θ).

AERMET defines the stability of the PBL by the sign of H (convective for $H > 0$ and stable for $H < 0$). Although AERMOD is capable of estimating meteorological profiles with data from as little as one measurement height, it will use as much data as the user can provide for defining the vertical structure of the boundary layer. In addition to PBL parameters, AERMET passes all measurements of wind, temperature, and turbulence in a form AERMOD needs.

[3] Albedo: the fraction of the incident sunlight that is reflected
[4] Bowen ratio: the ratio of heat used for "Sensible Heat" (conduction and convection) to heat used for "Latent Heat" (vaporization of water) expressed in percent.

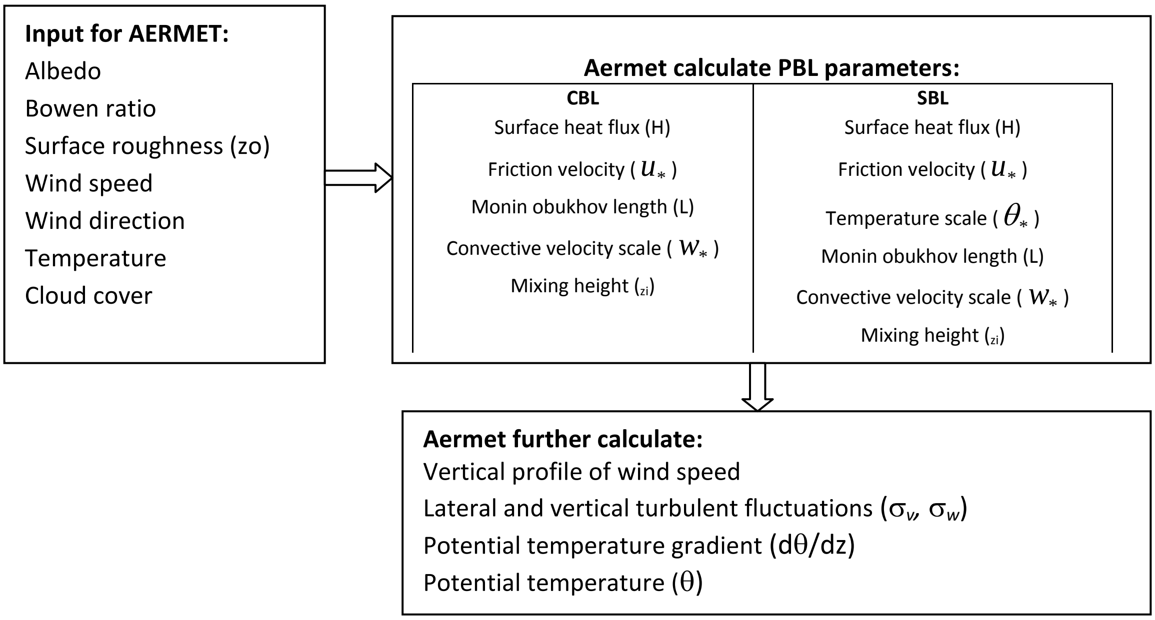


Figure 3 Flow of AERMET Estimating PBL Parameters

AERMOD Terrain Pre-processor (AERMAP)

Using a relatively simple approach, AERMOD incorporates current concepts about flow and dispersion in complex terrain. Where appropriate the plume is modelled as either impacting and/or following the terrain. This approach has been designed to be physically realistic and simple to implement while avoiding the need to distinguish among simple, intermediate and complex terrain, as required by other regulatory models. As a result, AERMOD removes the need for defining complex terrain regimes. All terrain is handled in a consistent and continuous manner while considering the dividing streamline concept (Snyder et al. 1985) in stably stratified conditions.

The AERMIC terrain pre-processor AERMAP uses gridded terrain data to calculate a representative terrain-influence height (h_c), also referred to as the terrain height scale. The terrain height scale h_c, which is uniquely defined for each receptor location, is used to calculate the dividing streamline height. The gridded data needed by AERMAP is selected from Digital Elevation Model (DEM) data. AERMAP is also used to create receptor grids. The elevation for each specified receptor is automatically assigned through AERMAP. For each receptor, AERMAP passes the following information to AERMOD: the receptor's location (x_r , y_r), its height above mean sea level (z_r), and the receptor specific terrain height scale (h_c).

AERMIC Dispersion Model (AERMOD)

AERMOD is a steady-state plume model, which assumes that concentrations at all distances during a modelled hour are governed by the temporally averaged meteorology of the hour. The steady state assumption yields useful results since the statistics of the concentration distribution are of primary concern rather than specific concentrations at particular times and locations.

In the stable boundary layer (SBL)[5], AERMOD assumes the concentration distribution to be Gaussian in both the vertical and horizontal. In the convective boundary layer (CBL)[6], the horizontal distribution is also assumed to be Gaussian, but the vertical distribution is described with a bi-Gaussian probability density function (pdf). This behaviour of the concentration distributions in the CBL was demonstrated by Willis and Deardorff (1981) and Briggs (1993). Additionally, in the CBL, AERMOD treats "plume lofting," whereby a portion of plume mass, released from a buoyant source, rises to and remains near the top of the boundary layer before becoming mixed into the CBL. AERMOD also tracks any plume mass that penetrates into the elevated stable layer, and then allows it to re-enter the boundary layer when and if appropriate. For sources in both the CBL and the SBL AERMOD treats the enhancement of lateral dispersion resulting from plume meander.

In general, AERMOD models a plume as a combination of two limiting cases: a horizontal plume (terrain impacting) and a terrain-following plume. Therefore, for all situations, the total concentration, at a receptor, is bounded by the concentration predictions from these states. In flat terrain the two states are equivalent. By incorporating the concept of the dividing streamline height, in elevated terrain, AERMOD's total concentration is calculated as a weighted sum of the concentrations associated with these two limiting cases or plume states (Venkatram et al. 2001).

The general concentration equation, which applies in stable or convective conditions, is given by:

$$C_T\{x_r,y_r,z_r\} = f \cdot C_{c,s}\{x_r,y_r,z_r\} + (1-f)C_{c,s}\{x_r,y_r,z_p\} \qquad \textbf{Eq. 1}$$

where $C_T\{x_r, y_r, z_r\}$ is the total concentration, $C_{c,s}\{x_r, y_r, z_r\}$, is the contribution from the horizontal plume state (subscripts c and s refer to convective and stable conditions, respectively), $C_{c,s}\{x_r, y_r, z_p\}$ is the contribution from terrain-following state, f is the plume state weighting function, $\{x_r, y_r, z_r\}$ is the coordinate representation of a receptor (with z_r defined relative to stack base elevation), $z_p=z_r-z_t$ is the height of a receptor above local ground, and z_t is the terrain height at a receptor. **Figure 4** illustrates the relationship between the actual plume and AERMOD's characterization of it.

[5] Stable Boundary Layer (SBL): a cool layer of air adjacent to a cold surface of the earth, where temperature within that layer is statically stably stratified.

[6] Convective Boundary Layer (SBL): a type of atmospheric boundary layer characterized by vigorous turbulence tending to stir and uniformly mix, primarily in the vertical, quantities such as conservative tracer concentrations, potential temperature, and momentum or wind speed.

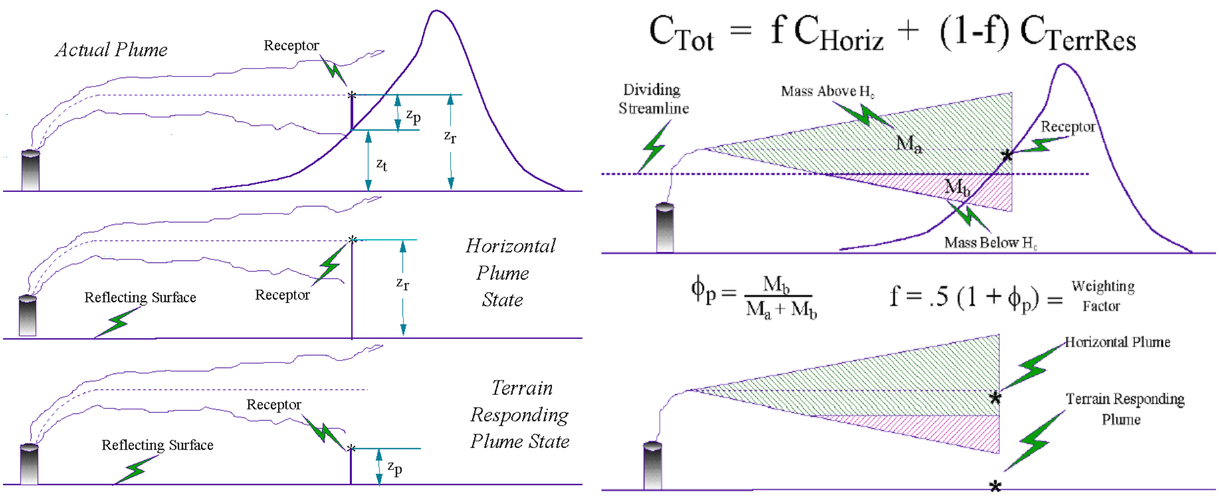


Figure 4 AERMOD Two State Approach.

(The total concentration predicted by AERMOD is the weighted sum of the two extreme possible plume states).

The general form of the expressions for concentration in each term of **eq. 1** for both the CBL and the SBL can be written as follows

$$C\{x,y,z\} = \left(Q/\tilde{u}\right) P_y\{y;x\}\, P_z\{z;x\}$$ **Eq. 2**

here Q is the source emission rate, u is the effective wind speed, and P_y and P_z are probability density functions (pdf) which describe the lateral and vertical concentration distributions, respectively.

Concentration Predictions in the CBL

In AERMOD, the dispersion formulation for the convective boundary layer (CBL) represents one of the more significant model advances by comparison with existing regulatory models. One assumes that plume sections are emitted into a travelling train of convective elements – updrafts and downdrafts - that move with the mean wind. The vertical and lateral velocities in each element are assumed to be random variables and characterized by their probability density functions (pdf). The mean concentration is found from the pdf of the position of source-emitted “particles”; this position pdf in turn is derived from the pdf of the lateral and vertical velocities as described by Weil et al. (1997); also see Misra (1982), Venkatram (1983), and Weil (1988a).

In the CBL, the pdf of the vertical velocity (*w*) is positively skewed and results in a non-Gaussian vertical concentration distribution, F_z (Lamb 1982). The positive skewness is consistent with the higher frequency of occurrence of downdrafts than updrafts; for an elevated non-buoyant source the skewness also leads to the decent of the plume centreline, as defined by the locus of maximum concentration (Lamb 1982; Weil 1988a).

Figure 5 presents a schematic representation of an instantaneous plume in a convective boundary layer and its corresponding ensemble average. The base concentration prediction in AERMOD is representative of a one hour average.

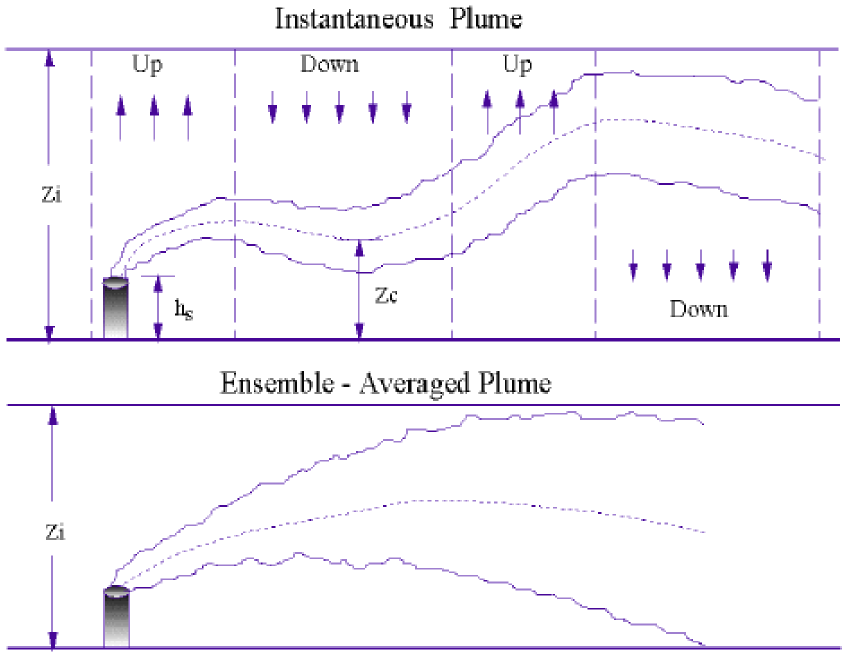


Figure 5 Instantaneous And Corresponding Ensemble-Averaged Plume in the CBL

The direct transport of plume material to the ground is treated by the "direct" source located at the stack. That is, the direct source treats that portion of the plume's mass to first reach the ground, and all subsequent reflections of the mass at $z = z_i$ and 0 (where z_i is the mixed layer height in the CBL (Cimorelli et al., 2004).

For plume segments or particles initially rising in updrafts, an "indirect" or modified-image source is included (above the mixed layer) to address the initial quasi-reflection of plume material at $z = z_i$, i.e., for material that does not penetrate the elevated inversion. This source is labelled "indirect" because it is not a true image source (i.e., as is found in models such as ISC) - the plume is not perfectly reflected about z_i. Thus, the indirect source treats that portion of the plume's mass that first reaches z_i and all subsequent reflections of that particular mass at $z = 0$ and z_i,

For the indirect source, a plume rise (Δh_i) is added to delay the downward dispersion of material from the CBL top (see **Figure 6**); this mimics the plume's lofting behaviour, i.e., the tendency of buoyant plumes to remain temporarily near z_i and resist downward mixing. For non-buoyant sources the indirect source reflection at $z = z_i$. Additionally, a "penetrated" source or plume (above the CBL top) is included to account for material that initially penetrates the elevated inversion but is subsequently re-entrained by and disperses in the growing CBL.

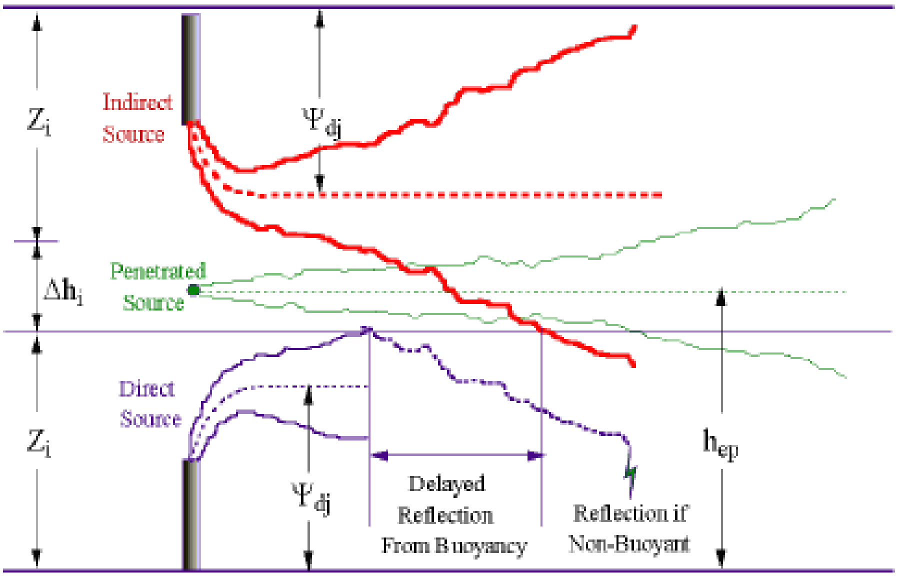


Figure 6 AERMOD's Three Plume Treatment of the CBL

In line with the above concepts there are three main mathematical sources that contribute to the modelled concentration field: 1) the direct source (at the stack), 2) the indirect source, and 3) the penetrated source. The strength of the direct source is f_pQ where Q is the source emission rate and f_p is the calculated fraction of the plume mass trapped in the CBL ($0 \leq f_p \leq 1$). Likewise, the indirect source strength is f_pQ since this (modified image) source is included to satisfy the no flux boundary condition at $z = z_i$ for the trapped material. The strength of the penetrated source is $(1- fp)Q$, which is the fraction of the source emission that initially penetrates into the elevated stable layer. In addition to the three main sources, other image sources are included to satisfy the no-flux conditions at $z = 0$ and z_i.

In AERMOD, the total concentration (C_c) in the CBL is found by summing the contribution from the three sources. For the horizontal plume state, the C_c is given by:

$$C_c\{x_r,y_r,z_r\} = C_d\{x_r,y_r,z_r\} + C_r\{x_r,y_r,z_r\} + C_p\{x_r,y_r,z_r\}$$ **Eq. 3**

where C_d, C_r, and C_p are the contributions from the direct, indirect and penetrated sources, Following Weil et al. (1997), the concentration due to the direct plume is given by:

$$C_d\{x_r,y_r,z\} = \frac{Qf_p}{\sqrt{2\pi}\,\tilde{u}} F_y \cdot \sum_{j=1}^{2}\sum_{m=0}^{\infty}\frac{\lambda_j}{\sigma_{zj}}\left[\exp\left(-\frac{\left(z-\Psi_{dj}-2mz_i\right)^2}{2\sigma_{zj}^2}\right)+\exp\left(-\frac{\left(z+\Psi_{dj}+2mz_i\right)^2}{2\sigma_{zj}^2}\right)\right]$$ **Eq. 4**

The concentration due to the indirect source is calculated from:

$$C_r\{x_r,y_r,z\} = \frac{Qf_p}{\sqrt{2\pi}\,\tilde{u}} \cdot F_y \cdot \sum_{j=1}^{2}\sum_{m=1}^{\infty}\frac{\lambda_j}{\sigma_{zj}}\left[\exp\left(-\frac{\left(z+\Psi_{rj}-2mz_i\right)^2}{2\sigma_{zj}^2}\right)+\exp\left(-\frac{\left(z-\Psi_{rj}+2mz_i\right)^2}{2\sigma_{zj}^2}\right)\right]$$ **Eq. 5**

For the penetrated source the concentration expression has a Gaussian form in both the vertical and lateral directions. The concentration due to this source is given by:

$$C_p\{x_r, y_r, z\} = \frac{Q\left(1-f_p\right)}{\sqrt{2\pi}\,\tilde{u}\,\sigma_{zp}} F_y \cdot \sum_{m=-\infty}^{\infty}\left[\exp\left(-\frac{\left(z-h_{ep}+2mz_{ieff}\right)^2}{2\sigma_{zp}^2}\right)+\exp\left(-\frac{\left(z+h_{ep}+2mz_{ieff}\right)^2}{2\sigma_{zp}^2}\right)\right] \quad \textbf{Eq. 6}$$

Concentrations Prediction in the SBL

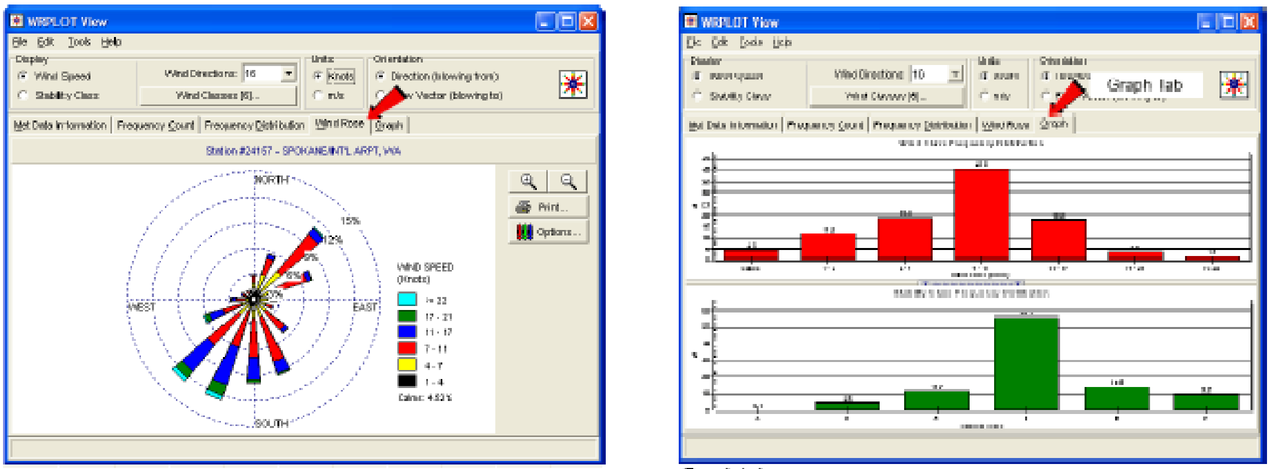
For stable conditions, the AERMOD concentration expression has the Gaussian form, and is similar to that used in many other steady-state plume models (e.g., HPDM (Hanna and Paine 1989)). The *Cs* is given by:

$$C_s\{x_r, y_r, z\} = \frac{Q}{\sqrt{2\pi}\tilde{u}\,\sigma_{zs}} \cdot F_y \cdot \sum_{m=-\infty}^{\infty}\left[\exp\left(-\frac{\left(z-h_{es}-2mz_{ieff}\right)^2}{2\sigma_{zs}^2}\right)+\exp\left(-\frac{\left(z+h_{es}+2mz_{ieff}\right)^2}{2\sigma_{zs}^2}\right)\right] \quad \textbf{Eq. 7}$$

where z_{ieff} is the effective mechanical mixed layer height, F_{zs} is the total vertical dispersion in the SBL and h_{es} is the plume height (i.e., stack height plus the plume rise).

WRPLOT View

WRPLOT View is a Windows program that generates wind rose statistics, frequency tables and graphs for a wide variety of surface data file formats (SCRAM, CD144, HUSWO, SAMSON, etc.), and for the ISC pre-processed met data file (**Figure 7**)



Wind Rose tab *Graph tab*

Figure 7 WRPLOT View Windows

MM5 Modelling at Lakes Environment

Since it is difficult to derive the hourly meteorological data for ISC AERMOD from surface station in Indonesia, the meteorological data were be ordered from lakes environment in weblakes.com This part is designed to provide a brief description of MM5 modelling at Lakes Environmental. The MM5 modelling focuses on generating high resolution meteorological data with the objective of gathering enough information to create AERMOD meteorological input files.

For AERMOD, Lakes Environmental generates the surface met file in SAMSON format and the upper air met file in TD-6201 format from hourly MM5 results. These two files are input into the AERMET pre-processor to produce the .SFC and .PFL files required by AERMOD. Lakes Environmental has chosen MM5 modelling options based on publications of studies for high resolution (small grids) evaluation runs.

MM5 (5th-generation Mesoscale Model) is a prognostic meteorology model developed by Pennsylvania State University and the U.S. National Centre for Atmospheric Research (NCAR). The model is a limited-area, non-hydrostatic, terrain-following sigma-coordinate model designed to simulate or predict mesoscale and regional-scale atmospheric circulation. MM5 was primarily developed using FORTRAN coding, and is still widely used as a community model even though formal development of the model has ended.

MM5 cannot directly use conventional meteorological data from airport reports. Instead, the model uses objective analysis of global weather reports. Objective analysis is a process of analysing the observed data and outputting them into a regular grid. The meteorological field is "balanced" to take account of the energy and momentum equations of the atmosphere. These objective analyses are products of global models, which are maintained by national weather centres or federal agencies such as UKMO (United Kingdom Meteorological Office) or NCEP (National Centre for Environmental Protection).

Lakes Environmental has obtained NCEP Global Reanalysis data for input to MM5, from 1999 to 2008 (and beyond as further data becomes available). The NCEP reanalysis has a resolution of 2.5 degrees by 2.5 degrees for the entire globe, given every 6 hours. The reanalysis data incorporates global weather data. **Figure 8** presents an example for the Great Lakes region of North America. The station numbers in the figure below show which weather stations were used for the re-analysis data. Note that these stations do not directly provide the data used for MM5 output; they serve as input into the MM5 model.

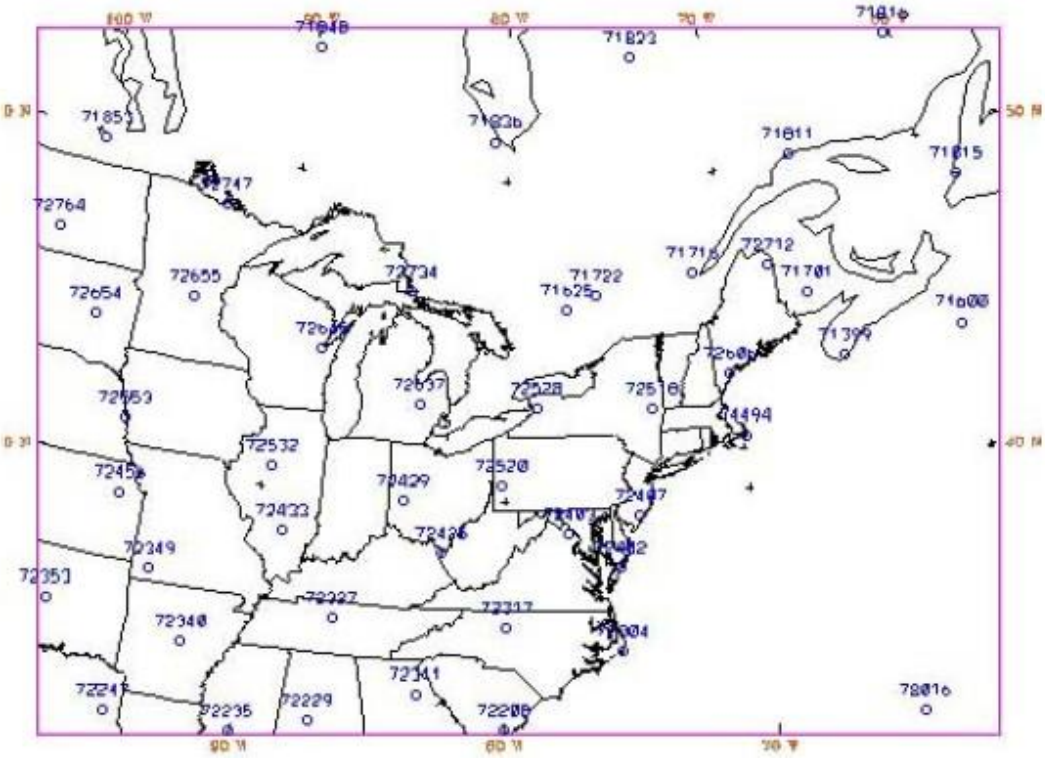


Figure 8 Sample MM5 domain with meteorological stations

Modelling Nested Grids Domain

MM5 uses a nested grid approach. In this way, an area of interest can be modelled without the penalty of excessive run times created by having a fine grid over the entire modelling domain. Depending on the application, Lakes Environmental employs a 12 km grid or a 4 km grid spacing at the highest resolution (internal) grid. MM5 data for the AERMOD model is available only in 12 km resolution.

Four-Dimensional Data Assimilation (FDDA)

Four-Dimensional Data Assimilation, or FDDA for short, is used in MM5 modelling. Specifically, analysis or grid nudging is applied – Newtonian relaxation terms are added to the prognostic equations for wind, temperature, and water vapour. These terms relax the model value towards a given analysis. The model linearly interpolates the analyses in time to determine the value towards which the model relaxes its solution

Working Procedure

The working procedure can be briefly described as follows:

1. All necessary data were collected to run the dispersion model as well as for model analysis;
2. Quality control and quality assurance of collected data were be carried out, in order to get a reliable data for model data input;
3. Running software for meteorological data using AERMET View;
4. Running software for statistical presentation of meteorological data using WRPLOT View;
5. Running software for topographical map generation by AERMAP;
6. Running software for particulate and gas dispersion using ISC-AERMOD View;
7. Interpretation and analysis of model dispersion output in the form of isopleth maps.

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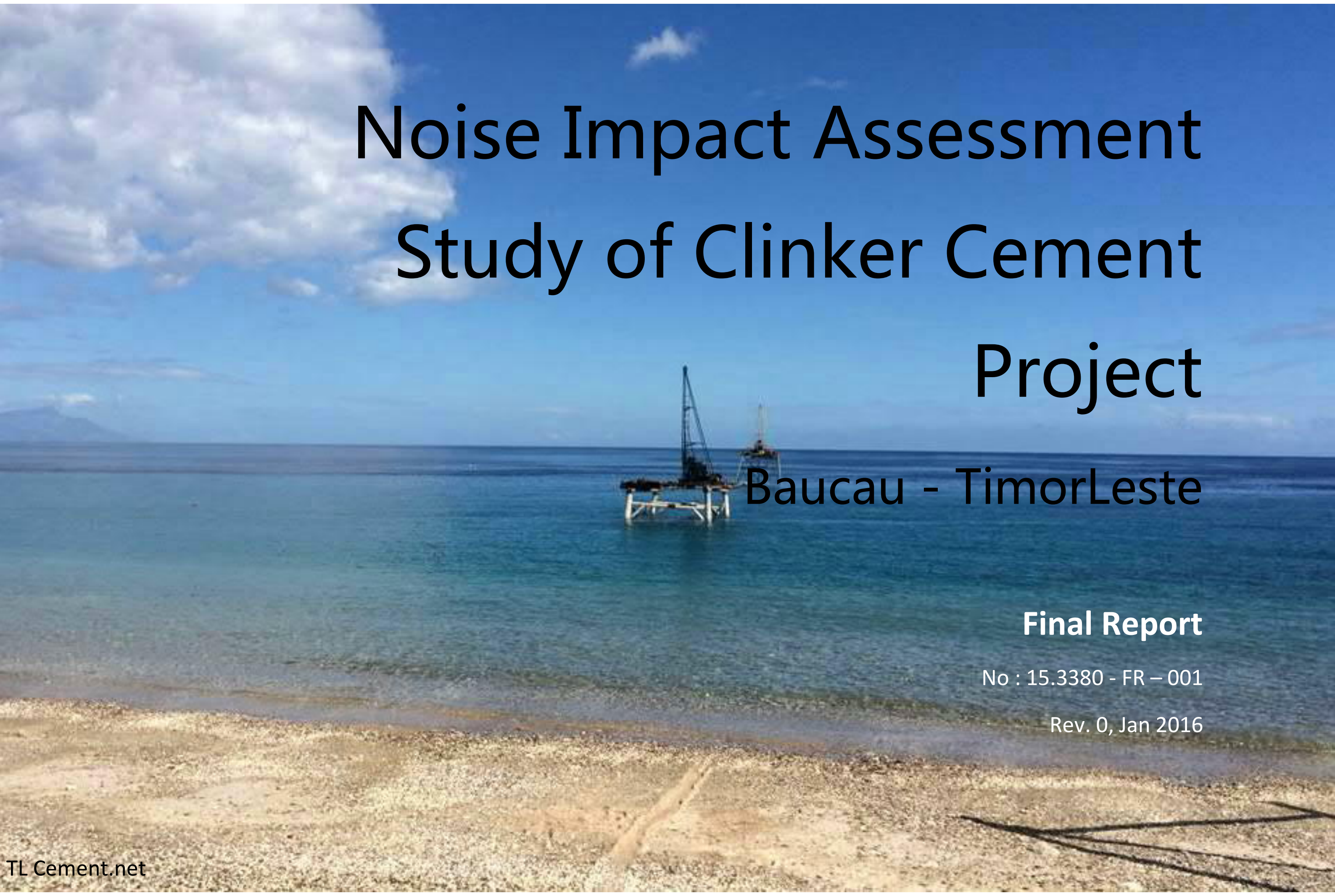
Appendix 2 Noise Impact Assessment Report

Cement
Your Dream, We will Build!

TL CEMENT Lda.



Noise Impact Assessment Study of Clinker Cement Project

Baucau - TimorLeste

Final Report

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TL Cement.net

Prepared by:

PT. **BITA** BINA SEMESTA

CONTENTS

EXECUTIVE SUMMARY

With a view to expand cement manufacturing business, a new company TL Cement LDA (TLC) has been established at Baucau in Timor-Leste. In the construction and operational phases, heavy equipment used will become a new source of noise in the area TL Cement. During the development, noise emission will occur continuously, therefore it is necessary to model the noise dispersion with the aim to predict the distribution of noise caused by activities and actions during construction and operations phase in TL Cement. This report provides an analysis of noise prediction during construction and operation phase. To obtain reliable noise prediction results, a study on the effects of noise distribution is done with reference to ISO 9613-2. ISO 9613-2 describes a method for calculating the attenuation of sound during propagation outdoors in order to predict the levels of vironmental noise at a distance from a variety of sources with considerations of geometrical attenuation, atmospheric absorption, ground effect, reflection from surfaces, screening by obstacles, and the presence of housing, foliage, and industrial site along the propagation path. Seven locations which represent sensitive receptors around TL Cements had been chosen to represent the noise baseline around the project area. The site selection was carried out based on the considerations of locations which will undergo the impact of noise from the cement plant activities and are occupied by local people.

Results from the predictions shows that during the construction phase, predicted noise level in seven sensitive receptors points exceeds the noise limit EPA 550/9-74-004. In N01, predicted noise level during construction exceeds the noise limit by 9 dBA. In N02, predicted noise level during construction exceeds the noise limit by 12 dBA. In N03 and N06, predicted noise level exceeds the noise limit by 13 dBA. In N04, predicted noise level during construction exceeds the noise limit by 19 dBA. In N05, predicted noise level during construction exceeds the noise limit by 26 dBA. In N07, predicted noise level during construction exceeds the noise limit by 14 dBA.

During the operation phase, predicted noise level in six sensitive receptors points exceeds the noise limit EPA 550/9-74-004. In N02, predicted noise level during operation exceeds the noise limit by 6 dBA. In N03, predicted noise level during operation exceeds the noise limit by 7 dBA. In N04, predicted noise level during operation exceeds the noise limit by 13 dBA. In N05, predicted noise level during operation exceeds the noise limit by 18 dBA. In N06, predicted noise level during operation exceeds the noise limit by 4 dBA. In N07, predicted noise level during operation exceeds the noise limit by 7 dBA. While in N01, predicted noise level during operation is in allowable level.

In general, modelling results indicate that the predicted impacts of TL Cement development have quite significant impact on the increase in noise levels in areas around TL Cement. Therefore, mitigation must be implemented to keep the noise level in residential areas is in allowable level. To reduce the impact of noise both in the construction and the operation phase, there are mitigation options like design options, mitigation at the source, mitigation along the path, and mitigation at the receptors.

1. INTRODUCTION

1.1 Brief Project Description

TL Cement LDA, a privately-owned company, proposes to construct a Greenfield cement manufacturing project in Baucau Municipality, Timor-Leste. The project will produce approximately 1.65 million tons per annum (Mtpa) of Portland cement clinker.

Clinker refers to small lumps (3.0-25.0 mm diameter), produced by heating limestone and other materials such as clay and sand in a cement kiln. Clinker, if stored in dry conditions, can be kept for several months without appreciable loss of quality. Because of this, it can easily be handled by ordinary mineral handling equipment, clinker is traded internationally in large quantities. Clinker is then ground to a fine powder, along with gypsum and other substances to produce useable cement.

The proposed project will provide cement for both domestic use and international sale. A feasibility study is currently being undertaken to demonstrate the commercial viability of the project.

The proposed project represents a significant investment of approximately $350 million and the largest industrial project undertaken in Timor-Leste to date. It is anticipated to create 1000 jobs at the peak of the construction. It will then continue to have 700 permanent employees during operation. The project aims to develop local capacity and will develop a training center.

The spin off benefit would be indirect employment to local community members, through the multiplier effect due to downstream socio-economic benefits and consequent improvement in the living conditions of local population in the project area.

A. <u>Cement Clinker Plant</u>

The plant includes clinkerisation and cement grinding facilities with a rated capacity of 5,000 tons per day (tpd) of clinker and 100 tons per hour (tph) of cement. The plant also includes a waste heat recovery (WHR) power plant.

Up to 60% of 0.53 Mtpa of cement will be sold in the local markets and balance 40% will be shipped to Australia in 8,000 Deadweight-Ton (DWT) ships either in bulk or in. Balance clinker of 1.15 Mtpa will be shipped in vessels of 40,000 DWT ships to Australia.

The project involves developing a green field plant including, but not limited, to the engineering, design, manufacturing and supply of new equipment for cement plant, a waste heat recovery based power plant, a captive thermal power plant of approx. 30 MW and Port (Double wharf jetties) about 1.5-2 Km from the plant site.

B. <u>Thermal Power Plant bottom and fly ash utilization</u>

The waste from the thermal power plant will be fly ash and bottom ash. The total ash will be utilised in the cement grinding for producing PPC based on the coal data and ash in the coal the fly/bottom ash generation will be approximately 50 t/day i.e. approx 16500 t/annum. This will produce around 66000 t/a of PPC based on 25% ash in PPC. All ash from the thermal power plant will be transported pneumatically to the cement grinding section.

C. <u>Mines and Raw Materials</u>

The raw and fuel material requirements for the proposed plant are to be met from different sources as given in Table below.

Table 1.1 Raw Materials

No.	Material	Source	Source Locality	Remarks
1.	Limestone	Local	SucoTirilolo, Bahu, Caibanda, Triloca, Bucoli, Wailili and Fatumaca in administrative post Baucau, Vemasse and Venilele , Baucau Municipality	Primary raw material. Transported from mine site to crusher by trucks.
2.	Clay	Local	Suco Wailacama, Baucau administrative post in Baucau municipality	A corrective material. Transported from quarry to plant by road.
3.	Iron Ore	Import	Australia	A corrective material. Transported to Timor-Leste by ship or barge, offloaded at jetty, and transported to plant by belt and Pipe conveyor.
4.	Gypsum	Import	Australia or other	A corrective material. Transported to Timor-Leste by ship or barge, offloaded at jetty, and transported to plant by belt and pipe conveyor.
5.	Coal	Import	Australia/ Indonesia	Fuel source and corrective material. Transported to Timor-Leste by ship or barge, offloaded at jetty, and transported to plant by belt and Pipe conveyor.

D. Limestone Deposit

The limestone deposit is accessible from Baucau by a tar road. The mine is located about 1 km from the main road and Bucoli village. The mining area is located around 0.5 km from the coastline where a jetty is proposed to be constructed. The limestone concession area (I-1) which shall meet the initial limestone requirement of the plant covers an area of 576 ha. The deposit area is generally undulating and hilly. As observation result, the limestone bearing area is covered by thick or scattered trees, thorny bushes and tall grass.

E. Clay Deposit

Clay is found to occur close to the plant site in Suco Wailacama in Baucau administrative post, less than 10 km west of the plant site. Clay shall be used as corrective to compensate for silica and alumina deficiency in the raw mix. Clay is proposed to be transported to the plant site by trucks.

F. Jetty

A dedicated jetty is proposed at a distance of 2 km from the plant site. Inbound material, (e.g., coal, gypsum, iron ore) and outbound clinker shall be transported between the plant and the jetty by a 0.5 km long conveyor belt + 1.5 km Pipe Conveyor (fully enclosed). The maximum load during unloading is estimated as 1000 tons per hour and during loading is estimated as 1000 tons per hour.

G. Utilities

a. Power

Power will be supplied by captive thermal power plant of approximately 30 mega-watts (MW) capacity and Waste Heat Recovery power plant.

Power for initial phase of plant operation when cement grinding is commissioned will be from grid power. Tapping from the nearby grid line of 20 KV will be tapped and step down to 11 KV at the plant substation. Generator sets will be utilized for construction power.

Emergency power requirement for initial commissioning of cement grinding is not required. For full plant 1.5 MW generator will be required. Thermal power plant shall include black start power requirement separately.

b. Water Supply

The water requirement for the cement project shall be met from groundwater by drilling bore wells. A makeup water supply of approximately 3,150 m^3/day is required for operations including requirement of mines, colony and green belt which may be possible to obtain this from one or two boreholes.

An underground aquifer is reported to occur below the mining blocks. As there is no industry in the area, the exploitation of water resources during the operation is not expected to adversely affect the water availability in the area for other competing users.

A detailed hydro geological study is proposed to be carried out to assess the availability of groundwater in the area. Water shall be required for:

- Process Water Circuit
- Cooling water (required for machine cooling)
- Make-up water shall be provided while re-circulating water shall be in a close loop
- Water required for township
- Water for on-site facilities
- Construction and operations (dust suppression)

c. Waste Water

The cement plant is being designed as a Zero Discharge facility and there shall be no discharge of waste water outside the plant premises. All the process waste water shall be treated in Water Treatment Plant and reused for plantation purposes. The waste water generated from domestic activities shall also be treated and reused for dust suppression, green belt development to the extent possible.

d. Solid Waste

Domestic solid waste generated from plant and jetty area shall be segregated and will be sent to waste disposal site as allocated by the local administrative authorities.

1.2 Location Study

The proposed cement plant and marine jetty are located in Suco Tirilolo, Aldeia Osso-ua, in the Baucau administrative post of Baucau municipality, Timor-Leste. The location is about 120 km east of Dili and approximately 16 km west of Baucau.

The Proponent has been granted a Prospecting License for limestone over three blocks, including, Block I-1 (Bucoli North Area-1), covering areas of 576 ha. The prospecting blocks are spread over Sucos Tirilolo, Bahu, Caibada, Triloka, Bucoli, and Wailili in administrative posts of Baucau, Vemasse and Venilele in Baucau municipality.

Sources of clay are located at Suco Wailacama within 10 km from proposed plant site. Corrective iron ore and additive gypsum are proposed to be procured from Australia. Coal will be used as a fuel for the kiln and power supply at the cement plant and is proposed to be procured from either Indonesia or Australia. The location of plant, mines (Block I-1) and jetty are shown in figure below.

Source : *https://commons.wikimedia.org/wiki/File:Sucos_Baucau.png*
https://www.mof.gov.tl/about-the-ministry/statistics-indicators/sensus-fo-fila-fali/download-suco-reports/baucau-suco-reports/

Figure 1.1 Location of TL Cement Development Project

1.3 Scope Of Work

According to scope of works from WorleyParsons, the noise impact assessment study will assess the following task :

- Preparation of baseline status of the noise intensity of the study area;
- Preparation of extensive noise impact modeling is undertaken to predict the likelihood of impacts on sensitive receptors;
- Identifying avoidance measures or design mitigation measures.

2. ASSESSMENT CRITERIA

Noise level either as the result of primary measurement (baseline data) or prediction shall be compared to the international noise standard from EPA (Environmental Protection Agent) 550/9-74-004 as shown in **Table 2.1**. The standards are based on 'equivalent sound levels identified as requisite to protect the public health and welfare with an adequate margin of safety'. The most important feature of these guidelines is the recommended limit of 55 dBA L_{DN} for noise in residential areas. The limit has been widely used as the basis for community noise internationally.

Table 2.1 International Noise Standard from EPA 550/9-74-004

Measure		Indoor			Outdoor		
		Activity Interference	Hearing loss consideration	To protect against both effect	Activity Interference	Hearing loss consideration	To protect against both effect
Residential with outside space and farm residences	L_{dn}	45		45	55		55
	$L_{eq(24)}$		70			70	
Residential with no outside space	L_{dn}	45		45			
	$L_{eq(24)}$		70				
Commercial	$L_{eq(24)}$	(a)	70	70(c)	(a)	70	70(c)
Inside Transportation	$L_{eq(24)}$	(a)	70	(a)			
Industrial	$L_{eq(24)}$ (d)	(a)	70	70(c)	(a)	70	70(c)
Hospitals	L_{dn}	45		45	55		55
	$L_{eq(24)}$		70			70	
Educational	L_{dn}	45		45	55		55
	$L_{eq(24)}$ (d)		70			70	
Recreational Areas	$L_{eq(24)}$	(a)	70	70(c)	(a)	70	70(c)
Farmland and unpopulated land	$L_{eq(24)}$				(a)	70	70(c)

Code:

(a) Since different types of activities appear to be associated with different levels, identification of a maximum level for activity interference may be difficult except in those circumstances where speech communication is a critical activity.

(b) Based on lowest level

(c) Based only on hearing loss

(d) An Leq(8h) of 75 dB may be identified in these situations so long as the exposure over the remaining 16 h per day is low enough to result in a negligible contribution to the 24-h average, i.e., no greater than an Leq of 60 dB.

3. ENVIRONMENTAL BASELINE

Seven locations which represent sensitive receptors around TL Cement as shown in **Table 3.1**, **Figure 3.1** had been chosen to represent the noise baseline around the project area. The site selection was carried out based on the followings considerations:

- Locations which will undergo the impact of noise from the cement plant activities.
- Locations which are occupied by local people.

Noise baseline was measured every 5 seconds for 10 minutes for each measurement. The measurement is carried out to determine the equivalent noise level (Leq).

Basically, noise measurement was conducted to describe activities and noise background for 24 hours at TL Cement by measuring a minimum of 4 times at noon and 3 times at night. The measurement must be able to represent an interval of 16 hours during the day (6:00 to 22:00) and 8 hours during night (22:00 to 06:00).

Recapitulation of Leq and calculation of Ld, Ln, and Ldn can be seen in **Table 3.2**.

Table 3.1.Coordinates of noise baseline measurement point (representative locations of sensitive receptors)

Measurement Point	Location	Description	Zone	Easting	Northing
N01	Bahu	Settlement Area	52L	216790	9063590
N02	Check Point Triloca	Settlement Area	52L	210450	9060528
N03	Aldeia Parlementu	School Area	52L	212220	9065492
N04	Aldeia Osso-ua	Settlement Area	52L	209131	9065049
N05	Jetty Plan	Jetty Area	52L	207557	9065473
N06	Wailacama	Settlement Area	52L	204205	9060554
N07	Bucoli	Settlement Area	52L	207768	9060793

Simbol	X	Y
N.01	216790	9063590
N.02	210450	9060528
N.03	212220	9065492
N.04	209131	9065049
N.05	207557	9065473
N.06	204205	9060554
N.07	207768	9060793

Figure 3.1 Location of Noise Baseline Measurement

Figure 3.2 N-01, Location of Noise Measurement in Bahu

Figure 3.3 N-02, Location of Noise Measurement in Check Point Triloca

Figure 3.4 N-03, Location of Noise Measurement in Aldeia Parlemento

Figure 3.5 N-04, Location of Noise Measurement in Aldeia Osso-ua

Figure 3.6 N-05, Location of Noise Measurement in Jetty Plan

Figure 3.7 N-06, Location of Noise Measurement in Bucoli

Figure 3.8 N-07, Location of Noise Measurement in Wailacama

Table 3.2. Noise baseline measurement data L_{eq} and the calculated L_d,L_n,and L_{dn}

		Measurement Point						
		N01	N02	N03	N04	N05	N06	N07
Measurement of LAeq (dBA)	1	54.0	60.2	55.5	56.3	50.5	63.8	58.3
	2	54.4	58.8	43.6	52.8	49.9	57.4	55.9
	3	55.6	54.3	45.1	53.3	51.1	62.4	54.9
	4	64.2	60.1	48.9	48.6	51.6	62.8	58.1
	5	60.7	58.2	50.3	51.7	42.6	55.9	58.3
	6	53.6	59.4	50.2	49.7	47.3	41.2	58.1
	7	54.1	59.0	51.1	50.2	47.9	55.9	46.9
	8	52.8	57.9	46.2	50.0	47.9	38.3	43.7
	9	52.6	48.4	46.5	50.3	49.8	46.9	40.7
	10	57.5	53.3	47.5	49.5	50.2	54.1	43.6
	11	58.1	52.9	45.9	55.2	49.5	39.1	43.1
	12	52.5	56.4	50.2	52.8	49.2	56.5	50.6
Ldn (dBA)		58.45	58.97	50.99	54.83	51.92	59.48	55.34
Ld (dBA)		58.43	58.87	50.67	52.80	49.83	60.67	57.46
Ln (dBA)		53.53	54.07	46.57	51.66	48.78	52.85	46.06

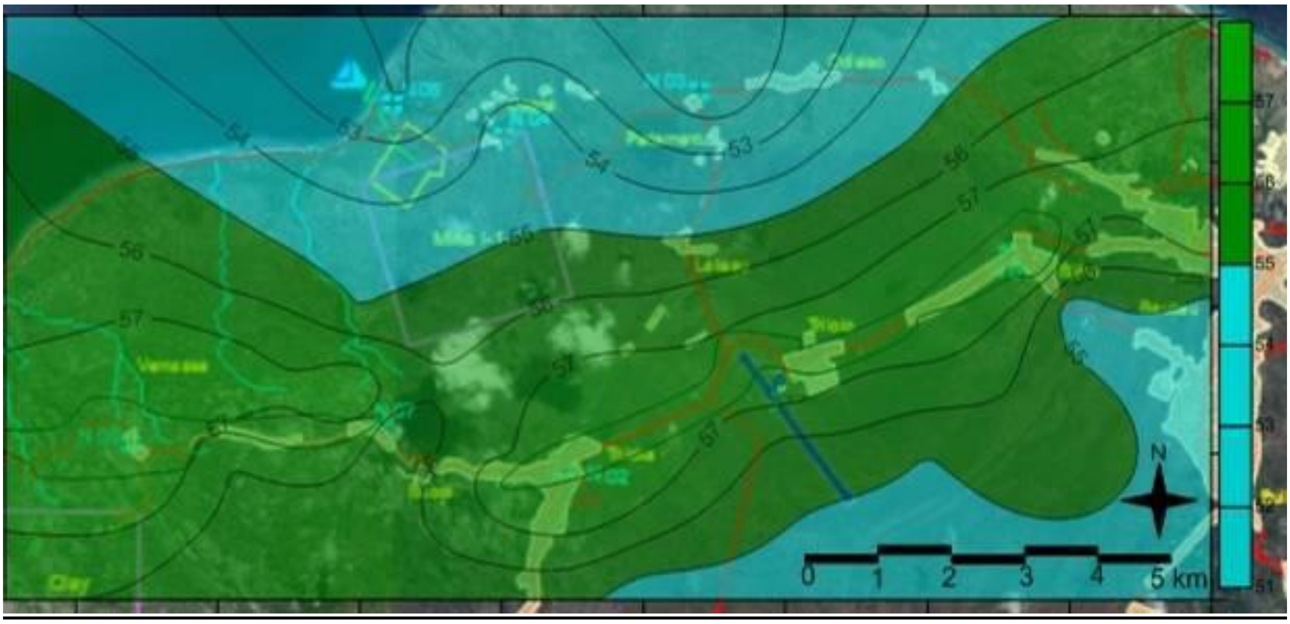


Figure 3.9 Estimated noise baseline in TL Cement (in dBA)

Based on **Table 3.2**, the value of Ldn in seven measurement points are 50.99 - 59.48 dBA. At the measurement point N03, N04, N05, and N07, Ldn values meet the noise quality standards with 3 dBA tolerance. While at the measurement point N01, N02, and N06, Ldn values slightly exceeded the noise quality standards.

Some measurement points with higher noise level were due to the cars or motorcycles that passed by during measurement. Therefore it is necessary to eliminate incidential noise from cars or motorcycle. Noise baseline level that has been adjusted by eliminating the incidential noise from cars or motorcycle can be seen in **Table 3.3** and **Fig 3.10**. From **Table 3.3**, it can be seen that noise baseline levels meet the community noise standard (see **Table 2.1**) with a tolerance of 3 dB.

Table 3.3.Noise baseline measurement data L_{eq} and the calculated L_d,L_n,and $L_{dn}$with incidential noise elimination

		Measurement Point						
		N01	**N02**	**N03**	**N04**	**N05**	**N06**	**N07**
Measurement of LAeq (dBA)	**1**	54.0			56.3	50.5		
	2	54.4		43.6	52.8	49.9		
	3	55.6	54.3	45.1	53.3	51.1		
	4			48.9	48.6	51.6		
	5			50.3	51.7	42.6		
	6	53.6		50.2	49.7	47.3	41.2	
	7	54.1		51.1	50.2	47.9		46.9
	8	52.8		46.2	50.0	47.9	38.3	43.7
	9	52.6	48.4	46.5	50.3	49.8	46.9	40.7
	10		53.3	47.5	49.5	50.2		43.6
	11		52.9	45.9	55.2	49.5	39.1	43.1
	12	52.5		50.2	52.8	49.2		50.6
Ldn (dBA)		56.27	55.52	50.20	54.83	51.92	46.34	50.71
Ld (dBA)		53.98	54.30	49.17	52.80	49.83	41.20	50.32
Ln (dBA)		53.53	50.77	46.57	51.66	48.78	42.03	46.06

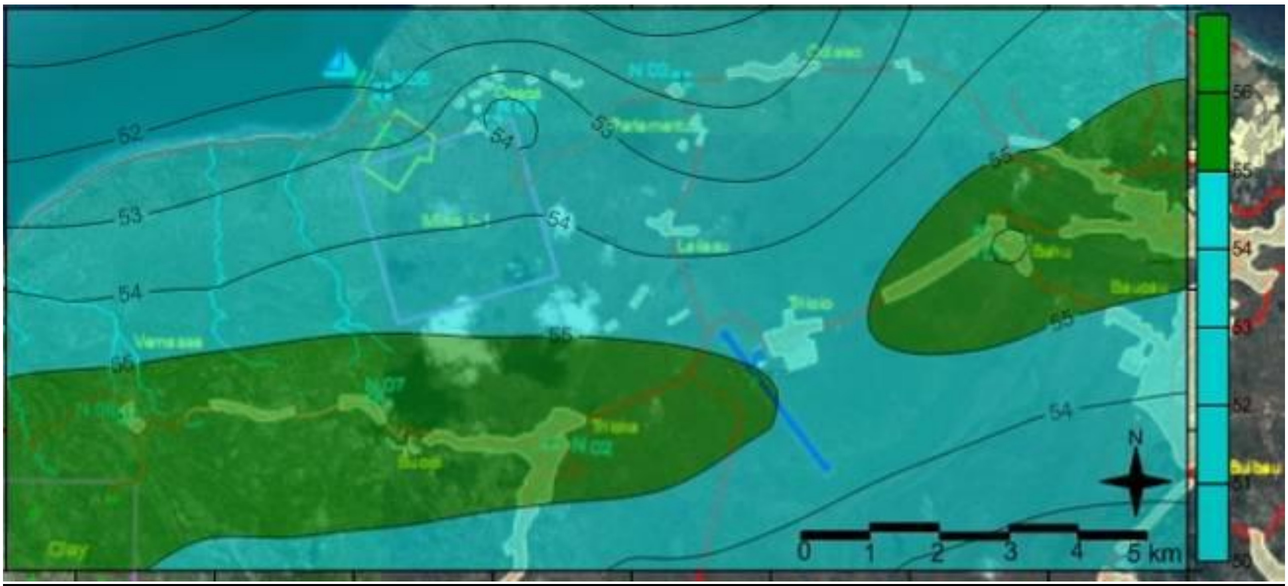


Figure 3.10 Estimated noise baseline in TL Cement with incidential noise elimination (in dBA)

4. ASSESSMENT METHOD

To obtain reliable results, a study on the effects of noise distribution is carried out using MATLAB® with reference to ISO 9613, the Attenuation of Sound during Propagation Outdoors. For the noise prediction of industrial sources the standard ISO 9613-2 is applied in most countries. However the noise mapping is conducted using Golden Surfer software.

In this chapter, modeling scenarios, formulas and standards used in calculating noise levels will be presented. Most formulas used refer to the International Standards Organization (ISO).

4.1 Propagation Noise Calculation using MATLAB®

MATLAB® is a software that can be used for data analysis, algorithm development, modeling, and a variety of other applications. MATLAB® is equipped with syntax, tools, and various mathematical functions that facilitate the analysis and modeling of the various approaches, so the results are expected to be produced more quickly.

This calculation is based on ISO 9613, the Attenuation of Sound during Propagation Outdoors describing a method for calculating the attenuation of sound during propagation outdoors in order to predict the levels of environmental noise at a distance from a variety of sources. This method is applicable in practice to a great variety of noise sources and environments. It is applicable, directly or indirectly, to most situations concerning road or rail traffic, industrial noise sources, construction activities, and many other ground-based noise sources. The agreement between calculated and measured values of the average sound pressure level for downwind propagation supports the estimated accuracy of calculation shown in **Table 4.1**. However, the ± 3 dB accuracy is still in tolerable level.

Table 4.1. Estimated accuracy of noise predictions based on ISO 9613-2

Height, h *)	**Distance, d** *)	
	0 < d < 100 m	**100 m < d < 1000 m**
0 < *h* < 5 m	± 3 dB	± 3 dB
5 m < *h* < 30 m	± 1 dB	± 3 dB

*) *h* is the mean height of the source and receiver.

d is the distance between the source and receiver.

NOTE – These estimates have been made from situations where there are no effects die to reflection or attenuations due to screening.

Attenuation that occurs during sound wave propagation in the outdoor experience is divided into attenuation due to the distance (divergence) from the sound source to the observation point, attenuation due to atmospheric absorption (atmospheric attenuation), ground effect attenuation, attenuation due to the objects that hinder the propagation of sound, etc.

The equivalent continuous sound pressure level at a receiver location shall be calculated for each point source from equation:

$$L_{fT} = L_w + D_c - A$$ **Equation 1**

$$L_p = L_w - 20\log(r) + DI - 11 - A$$ **Equation 2**

$$A = A_{div} + A_{atm} + A_{gr} + A_{bar} + A_{misc}$$ **Equation 3**

where L_p : sound pressure level, in decibels, received at distance r from noise source relative to a reference sound pressure

r : distance between noise source and receiver, in meter

L_w : sound power level, in decibels, produced by the point sound source relative to a reference sound power of one picowatt (1 pW)

D_c : the directivity correction, in decibels

A : Attenuation that occurs during propagation from the point sound source to the receiver.

A_{div} : the attenuation due to geometrical divergence

A_{atm} : the attenuation due to atmospheric absorption

A_{gr} : the attenuation due to ground effect

A_{bar} : the attenuation due to a barrier

A_{misc} : the attenuation due to miscellaneous other effects

The distance r is calculated based on elevation of source and the coordinate of the receiver points. The directional characteristics of a sound source DI are highly influenced by nearby reflecting surfaces. Take the example of an omni directional source - one that radiates sound equally in all directions. Imagine that this source is placed on a flat, reflecting surface. Its sound output is now constrained within half of the space that it would be if the surface were not present. So, all of the energy is constrained within half the space, therefore the sound intensity in that space is twice as great. This is equivalent to a 3 dB increase in level.

All sources are considered to be incoherent (independent) and can be calculated separately. Thus, the total sound pressure level due to all noise sources at each area becomes:

$$L_{p_{tot}} = 10Log\left(\sum_{n=1}^{\infty} 10^{Lp_n/10}\right)$$ **Equation 4**

Due to data limitations (no octave bands data and barrier available), this modelling only takes into account the attenuation due to the geometrical divergence, the attenuation due to ground effect, and the attenuation due to the shrubs in the savanna area.

4.1.1 Attenuation due to Geometrical divergence (A_{div})

Attenuation due to geometrical divergence is calculated using the following equation:

$$A_{div} = [20Log(\frac{d}{d_o}) + 11]\ dB$$ **Equation 5**

where: d : the distance from the source to receiver, in metres

d_o : the reference distance (= 1 m).

4.1.2 Attenuation due to Atmospheric Absorption (A_{atm})

Attenuation due to atmospheric absorption is calculated using the following equation:

$$A_{atm} = \frac{\alpha d}{1000}$$ **Equation 6**

α is the atmospheric attenuation coefficient, in decibels per kilometre for each octave band at the midband frequency (see the example of atmospheric attenuation coefficient in **Table 4.2**).

Table 4.2. The example of atmospheric attenuation coefficient α

Temperature	Relative humidity	Atmospheric attenuation coefficient α, dB/km							
		Frequency, Hz							
°C	%	63	125	250	500	1000	2000	4000	8000
10	70	0.1	0.4	1.0	1.9	3.7	9.7	32.8	117
20	70	0.1	0.3	101	2.8	5.0	9.0	22.9	76.6
30	70	0.1	0.3	1.0	3.1	7.4	12.7	23.1	59.3
15	20	0.3	0.6	1.2	2.7	8.2	28.2	88.8	202
15	50	0.1	0.5	1.2	2.2	4.2	10.8	36.2	129
15	80	0.1	0.3	1.1	2.4	4.1	8.3	23.7	82.8

4.1.3 Attenuation due to Ground Effect (A_{gr})

Ground attenuation, Agr, is mainly the result of sound reflected by the ground surface interfering with the sound propagating directly from source to receiver.

The downward-curving propagation path (downwind) ensures that this attenuation is determined primarily by the ground surfaces near the source and near the receiver. This method of calculating the ground effect is applicable only to ground which is approximately flat, either horizontally or with a constant slope. Three distinct regions for ground attenuation are specified as follows:

1. The source region, stretching over a distance from the source towards the receiver of 30hs, with a maximum distance of dp (hs is the source height, and dp the distance from source to receiver, as projected on the ground plane);
2. The receiver region, stretching over a distance from the receiver back towards the source of 30hr, with a maximum distance of dp (hr is the receiver height);
3. A middle region, stretching over the distance between the source and receiver regions. If dp< (30hs + 30hr), the source and receiver regions will overlap, and there is no middle region.

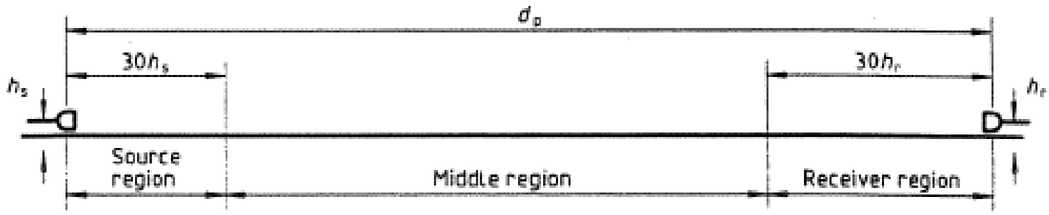


Figure 4.1 Three distinct regions for determination of ground attenuation

The acoustical properties of each ground region are taken into account through a ground factor G. Three categories of reflecting surface are specified as follows.

1. Hard ground, which includes paving, water, ice, concrete and all other ground surfaces having a low porosity. Tamped ground, for example, as often occurs around industrial sites, can be considered hard. For hard ground G = 0.
2. Porous ground, which includes ground covered by grass, trees or other vegetation, and all other ground surfaces suitable for the growth of vegetation, such as farming land. For porous ground G= 1.
3. Mixed ground: if the surface consists of both hard and porous ground, then G takes on values ranging from 0 to 1, the value being the fraction of the region that is porous.

To calculate the ground attenuation for a specific octave band, first calculate the component attenuations A_s for the source region specified by the ground factor G_s (for that region), $A_r$for the receiver region specified by the ground factor G_r and A_m for the middle region specified by the ground factor G_m, using the expressions in **Table 4.3**. The total ground attenuation for that octave band shall be obtained from equation:

$$A_{gr} = A_s + A_r + A_m$$ **Equation 7**

Table 4.3. Expressions to be used for calculating ground attenuation contributions A_s, A_r and A_m in octave bands

Frequency Hz	A_s or A_r 1) dB	A_m dB
63	-1.5	$-3q^{2)}$
125	-1.5 + G x *a'(h)*	$-3q(1-G_m)$
250	-1.5 + G x *a'(h)*	
500	-1.5 + G x *a'(h)*	
1000	-1.5 + G x *a'(h)*	
2000	-1.5 + (1-G)	
4000	-1.5 + (1-G)	
8000	-1.5 + (1-G)	

Notes

$a'(h)=1.5 + 3.0 \times e^{-0.12(h-5)^2}(1-e^{-dp/50}) + 5.7 \times e^{-0.09h^2}(1-e^{-2.8\times10^6 \times dp^2})$

$b'(h)=1.5 + 8.6 \times e^{-0.09h^2}(1-e^{-dp/50})$

$c'(h)=1.5 + 14.0 \times e^{-0.46h^2}(1-e^{-dp/50})$

$d'(h)=1.5 + 5.0 \times e^{-0.9h^2}(1-e^{-dp/50})$

1) For calculate A_s, take $G=G_s$ and $h=h_s$. For calculate A_r, take $G=G_r$ and $h=h_r$.
2) $q=0$, when $d_p <= (30h_s + 30h_r)$
$q=1-(30*(h_s+h_r)/d_p)$, when $d_p > (30h_s + 30h_r)$

Under the following specific conditions:

1. only the A-weighted sound pressure level at the receiver position is of interest,
2. the sound propagation occurs over porous ground or mixed ground most of which is porous
3. the sound is not a pure tone

and for ground surfaces of any shape, the ground attenuation may be calculated from equation:

$$A_{gr} = 4.8 - (2h_m / d)\left[17 + (300/d)\right] \geq 0 \quad dB$$ **Equation 8**

where h_m is the mean height of the propagation path above the ground, in metres; and d is the distance from the source to receiver, in metres (see **Figure 4.2**).

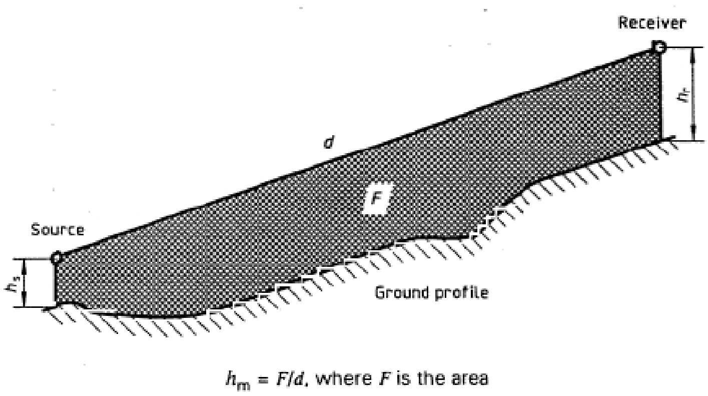


Figure 4.2 Method to evaluate h_m

In the calculation of attenuation due to ground effect, the ground surface around the area TL Cement is considered a combination between the porous and hard surfaces. Impedance effect due to the ground surface, calculated using the equation:

$$P \sim R^{-b}$$ **Equation 9**

where R is the distance of propagation and b is an attenuation coefficient that varies with the properties of the ground. (Albert, 2004).

4.1.4 Attenuation due to a barrier (A_{bar})

An object shall be taken into account as a screening obstacle (often called a barrier) if it meets the following requirements:

1. The surface density is at least 10 kg/m^2;
2. The object has a closed surface without large cracks or gaps;

3. The horizontal dimension of the object normal to the source-receiver line is larger than the acoustic wavelength λ at the nominal midband frequency for the octave band of interest; in other words $l_l+l_r>\lambda$ (see **Figure 4.3**).

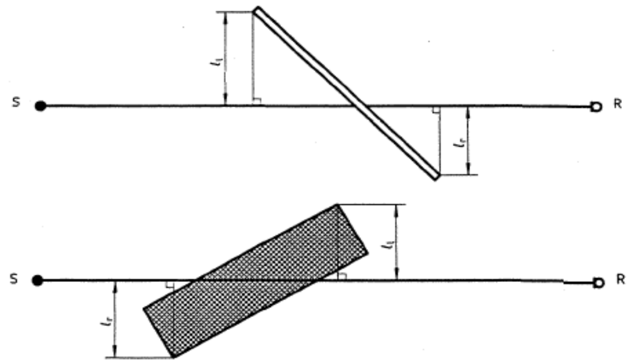


Figure 4.3 Plan view of two obstacles between the source (S) and the receiver (R)

Diffraction over the top edge and around a vertical edge of a barrier may both be important. For downwind sound propagation, the effect of diffraction (in decibels) over the top edge shall be calculated by:

$$A_{bar} = D_z - A_{gr} > 0$$ **Equation 10**

and for diffraction around a vertical edge calculated by:

$$A_{bar} = D_z > 0$$ **Equation 11**

where D_z is the barrier attenuation for each octave band calculated by:

$$D_z = 10Log\left[3+(C_2/\lambda)C_3 zK_{met}\right] \ dB$$ **Equation 12**

where C_2 = 20, 20, and includes the effect of ground reflections; if in special cases ground reflections are taken into account separately by image sources, C_2 = 40;

C_3 = 1, for single diffraction:

Or $C_3 = [1+(5\lambda/e)^2]/[(1/3)+(5\lambda/e)^2]$ for double diffraction

λ : the wavelength of sound at the nominal midband frequency of the octave band

z : the difference between the pathlengths of diffracted and direct sound

K_{met} : the correction factor for meteorological effects

E : the distance between the two diffraction edges in the case of double diffraction

4.1.5 Meteorological correction (C_{met})

Meteorological correction is calculated by:

$$C_{met} = 0, \ when\, d_p \le 10(h_s + h_r)$$
$$C_{met} = C_0\left[1-10(h_s+h_r)/d_p\right], \ when\, d_p > 10(h_s+h_r)$$ **Equation 13**

4.1.6 Miscellaneous Attenuation (A_{misc})

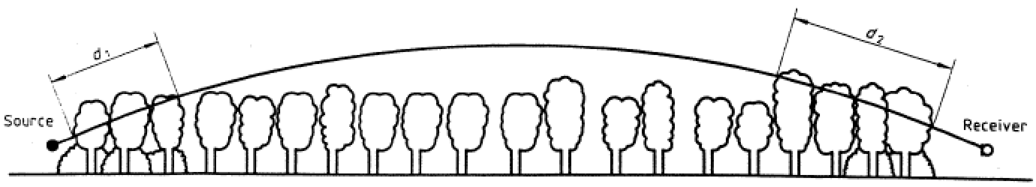
Other attenuation that counts is the attenuation due to vegetation and foliage, the attenuation due to the industrial area, as well as the attenuation due to the housing.

Attenuation due to the vegetation and foliage A_{fol}

Vegetation and foliage provides a small amount of attenuation, but only if it is sufficiently dense to fully block the view along the propagation path. The attenuation may be due to vegetation close to the source, close to the receiver, or both. Approximate values for the excess attenuation from dense foliage are listed in **Table 4.4**.

Table 4.4. Attenuation of noise due to propagating a distance d_f through dense foliage

Propagation distance d_f, meter	Frequency, Hz							
	63	125	250	500	1000	2000	4000	8000
10 > df > 20	Attenuation, dB:							
	0	0	1	1	1	1	2	3
20 > df > 200	Attenuation, dB/m:							
	0.02	0.03	0.04	0.05	0.06	0.08	0.09	0.12



NOTE — $d_f = d_1 + d_2$

For calculating d_1 and d_2, the curved path radius may be assumed to be 5 km.

Figure 4.4 Attenuation due to propagation through foliage increases linearly with propagation distance d_f through the foliage

Attenuation due to industrial site A_{site}

At industrial sites, attenuation can occur due to scattering from installation of equipment and other objects in an industrial area. The value of A_{site} is depend strongly on the type of site and equipment, therefore it is recommended that it is determined by measurement. **Table 4.5** shows great estimation of attenuation due to the industrial area. The attenuation increases linearly with the length of the curved path d_s through the installation (see **Figure 4.5**), with a maximum of 10 dB.

Table 4.5. Attenuation coefficient of an octave band of noise during propagation through installations at industrial plants

Frequency, Hz	63	125	250	500	1000	2000	4000	8000
A_{site}, dB/m	0	0.015	0.025	0.025	0.02	0.02	0.015	0.015

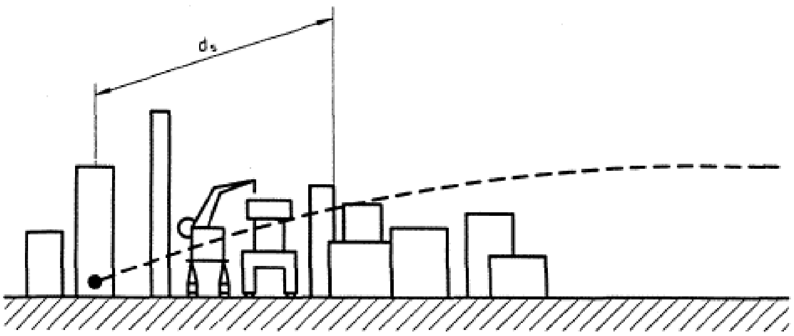


Figure 4.5 The attenuation A_{site}increaseslinearly with the propagation distance d_s through the installations at industrial plants

Attenuation due to housing A_{hous}

When either the source or receiver, or both are situated in a built-up region of houses, an attenuation will occur due to scrrening by the houses. However, this effect may largely be compensated by propagation between houses and by reflections from other houses in vicinity. Because the value of A_{hous} is very situation-dependent, such as calculation may be justified in practice. An approximate calue for A_{hous} may be estimated as follows:

$$A_{hous} = A_{hous,1} + A_{hous,2}$$ **Equation 14**

$$A_{hous,1} = 0.1Bd_b \quad dB$$ **Equation 15**

$$A_{hous,2} = -10Log\left[1-\left(p/100\right)\right] \quad dB$$ **Equation 16**

where Ahous,2 : included if there are well-defined rows of building near a road, a railway, or a similar coridor

B : the density of the buildings along that path given by the total plan area of the houses divided by the total ground area

d_b : the length of the sound path through the houses, as seen in **Figure 2.4**.

p : the percentage of the length of the façades relative to the total length of the road or railway in vicinity

4.2 SURFER

Surfer is a full-function 3D visualization, contouring and surface modeling software package. Surfer is used extensively for terrain modeling, bathymetric modeling, landscape visualization, surface analysis, contour mapping, watershed and 3D surface mapping, gridding, volumetrics, and much more.

Basically, Surfer transforms XYZ data into 3D shape, contour, or surface mapping. Surfer provides some options in gridding methods and parameters that can be changed as needed.

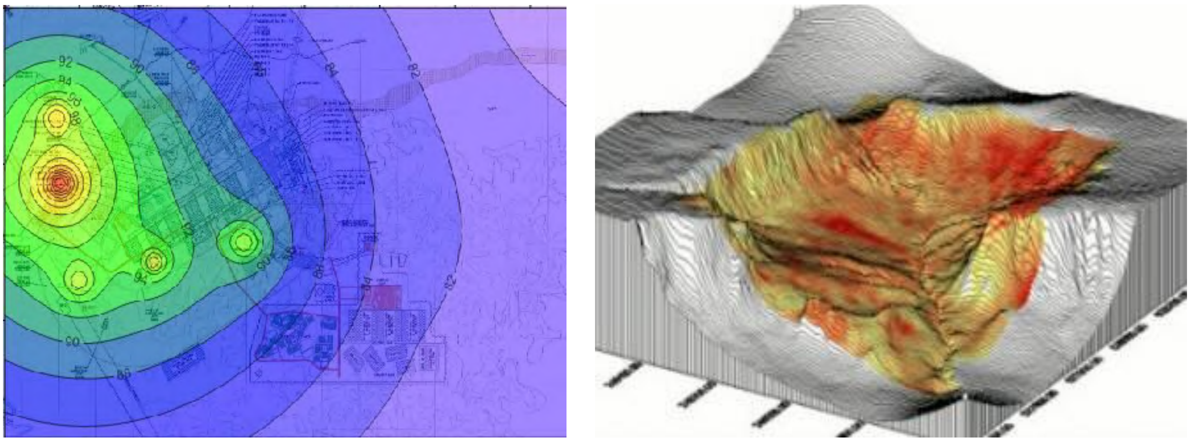


Figure 4.6 Examples of SURFER visualization output data

4.2.1 Surfer Gridding Methodology

Surfer offers many different grid based maps, such as 2D contour maps and 3D surface maps. To create a grid based map, a grid file must be provided. To create a grid file, Surfer takes XYZ data and uses it to create a regularly spaced grid file, composed of grid nodes. Each grid node is located at a particular XY location and has a Z value associated with it. Although the algorithms are computed internally in Surfer, choosing the best gridding method for the data can be difficult. Surfer has several different options for gridding methods, but for this project the methods used is *Kriging* method.

Kriging is one of the more flexible and accurate gridding methods; typically the one that is recommended when gridding data. Kriging is effective because it produces a good map for most data sets. It also can compensate for clustered data by giving less weight to the cluster in the overall prediction. One of the disadvantages to Kriging is that it can be slower than other methods. It also can extrapolate grid values beyond the range of the data's Z values.

Each grid node value is based on the known data further from the node will have less weight in the estimation of the node. For example, to compute points neighboring the node. Each data point is weighted by its distance away from the node. This way, points that are the Z value at grid node A, this equation is used:

$$Z_A = \sum_{i=1}^{n} W_i Z_i$$ **Equation 17**

Where Z_A is the estimated value of grid node A, n is the number of neighboring data values used in the estimation, Z_i is the value at location i with weight, W_i. The valueof weights will sum to 1 to make sure there is no bias towards clustered data points. The formula can get more complex if things such as drifts and a search radius are applied.

Below is a classed post map displaying a set of data values that were gridded using the Krigingmethod.

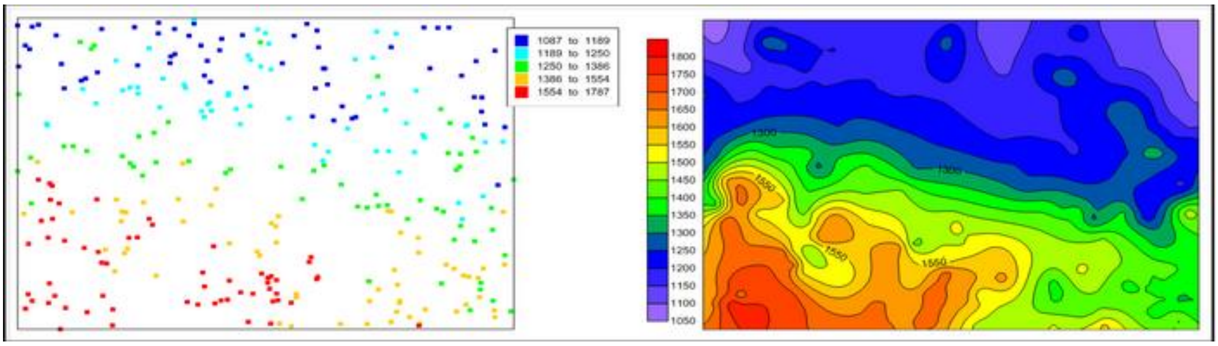


Figure 4.7 The classed post map, left, represents scattered elevation data that producedthe contour map, right, using theKriging gridding method.

4.3 Modelling Procedures

Modelling procedures can be described as follows:

1. Collecting all the necessary input data for the model, including parameters and noise source data (the location of the sound source and the generated power source), as well as other supporting data that are useful for the analysis of modeling results.
2. Checking of the data collected quality (quality control /and quality assurance)
3. Calculation using MATLAB®
4. Presentation of results using SURFER.
5. Interpretation and analysis of the modeling result.

4.4 Modelling Scenarios

Cement TL development and operational activities could potentially improve noise level at TL Cement area. In predicting noise, type and duration of activities and equipment used is taken into account.

Noise impact during Cement TL development and operational is mostly due to the activities during the construction phase. The actions and activitied during Cement TL Development Project includes the following activities:

- Activities and actions during construction are movement of manpower, machinery, and materials, site clearing, leveling, and excavation, civil construction, mechanical construction, camp, and jetty.
- Activities and actions during operation phase are excavation of limestone and clay from the captive mines, crushing of limestone and clay, transportation of limestone from mines to plant site, transportation of other correctives to the plant site, preparation of raw meal by adding correctives to limestone, clinkerisation of raw meal, cooling and heat recovery, blending & grinding of clinker by adding additives, packing and dispatch, ship traffic, transportation of raw material like coal, additives, etc. to plant by belt conveyor, and transportation of outbound clinker by belt conveyor.

The equipment used in construction and operations activities includes equipment for civil works and equipment for the mechanical work. Based on the type of activity undertaken, duration of activities and equipment used, noise levels increase is predicted. As noted in Chapter 3, scenario modeling was based on the plan of construction and operation activities in each area of TL Cement. Then modeling of each construction and operation activities is also performed in all areas simultaneously. The actual noise value will depend on variations of activities and the number of equipment used. This modeling assumed sound source reference distance is calculated from the midpoint of the sound source. In this modeling, attenuation due to the ground effect and due to foliage (shrubs) was also taken into account.

4.4.1 Input Parameters and Supporting Data

Modeling of noise dispersion involves interrelated data, for example characteristic and the location of noise source and scenarios used in the modeling. Therefore, the reliable data will determine the accuracy of the modeling results. The following is the relevant data input for the model.

Location of Noise Source and Receiver

Noise source from activities in TL Cement is divided into five areas, each of which has different activities. The location of activities is shown in **Figure 1.1**. The division of the area is the jetty area, plant area, and limestone mining area (Mine 1-1, Mine 1-2, and Mine 2). In the first phase, construction and operation activities are carried out only in **Jetty area, Plant area, and Mine 1-1**.

Source Noise Levels

Noise exposure level is determined by the number of noise sources and noise radiated power. Due to data limitation, assumptions and professional judgement from similar projects are used. **Table 4.6** shows the type, radiated sound power levels, and the amount of equipment used during construction and operations activities in TL Cement. Sound power data was taken from FHWA Highway Construction Noise Handbook. The noise source layout in TL Cement plant area is shown in **Figure 4.8**.

Modeling Scenario

The modeling was done in each area for each construction and operation activities. Then, it was also done for each construction or operations activities in jetty, plant, mine 1-1, and clay area simultaneously. The actual noise level will depend on variations of activities and the number of equipment used. This modeling assumed sound source reference distance is calculated from the midpoint of the sound source. In this modeling, attenuation due to the ground effect was also taken into account.

Table 4.6. Equipment Noise Emission Levels

Machinery/ Equipment	Power level (dB re 1 PicoWatt)	Construction					Operation			
		Jetty	Plant	Limestone Mine	Clay Mine	Stock Pile	Jetty	Plant	Mine 1-1	Clay
Water truck/fuel truck	112	2	5							
Pile driving rig	127	2	2							
Crane	117	2	5				2			

Machinery/ Equipment	Power level (dB re 1 PicoWatt)	Construction					Operation			
		Jetty	Plant	Limestone Mine	Clay Mine	Stock Pile	Jetty	Plant	Mine 1-1	Clay
Low &Flat bed trailer	116	2	5							
Prime mover	116		2							
Fork lift	117		3							

Table 4.7. Equipment Noise Emission Levels (cont)

Machinery/ Equipment	Power level (dB re 1 PicoWatt)	Construction					Operation			
		Jetty	Plant	Limestone Mile	Clay Mine	Stock Pile	Jetty	Plant	Mine 1-1	Clay
ship unloader	100						2			
Welding generators	105		5							
Conveyor	113						1	3		
Ship loader	100						1			
Crusher	103.5							3		
Raw mill	100.1							1		
Preheater	80							1		
Kiln	94							1		
Clinker silo	80.8							2		
Clinker cooler	78							1		
cement mill	99.4							1		
Cement silo	80.8							1		
packing plant	100							1		
Truck	112			7	4				4	4
storage	90							3		
office	65							1		
Pump, fan, compressor	100							3	4	4
Drilling	102								4	4
Excavator	85			3	1				2	2
Bulldozer/Ripper	95			1	1	3				
Wobbler feeder	80								1	1
Crushers	95								4	4
Box feeder	80								1	1

Machinery/ Equipment	Power level (dB re 1 PicoWatt)	Construction					Operation			
		Jetty	Plant	Limestone Mile	Clay Mine	Stock Pile	Jetty	Plant	Mine 1-1	Clay
Belt conveyor	113								4	4
Magnetic separator	80								1	1
Stackers	117								2	2
Motor Grader	95			1						
Wheel Loader	90					5				
Power generators	113	1	1				1	1	1	1

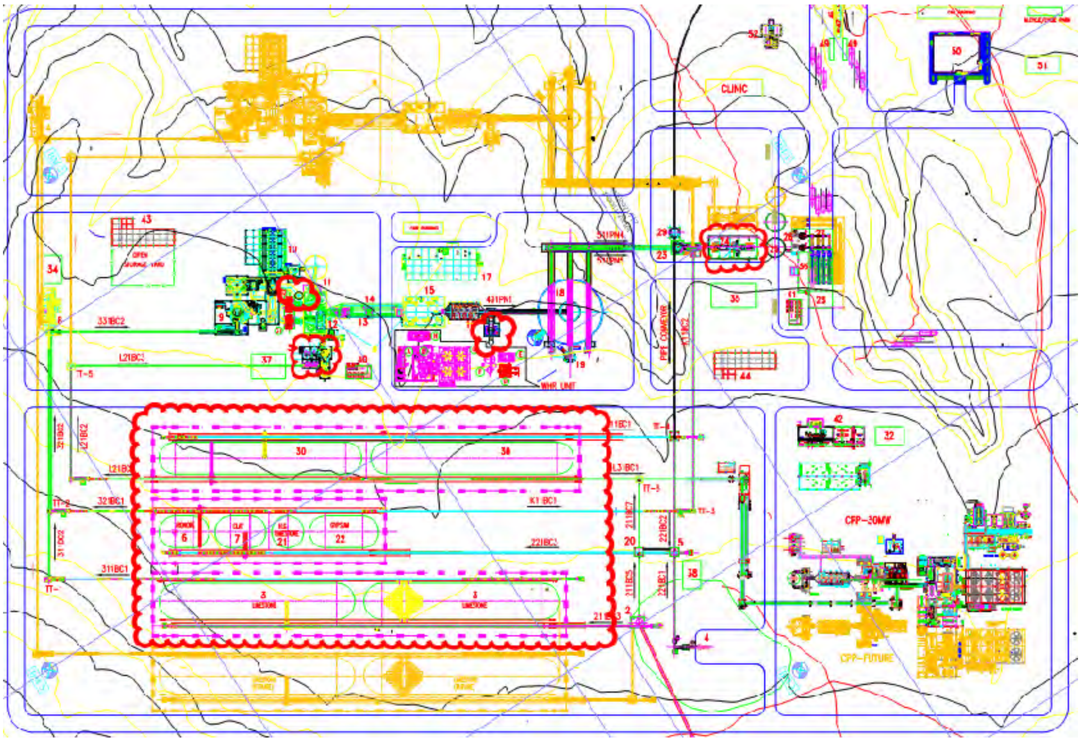


Figure 4.8 TL Cement Plant Layout

7

5. IMPACT ASSESSMENT

5.1 Construction Phase

Modeling noise contours during construction phase are shown in **Figure 5.1**, **Figure 5.2**, **Figure 5.3, Figure 5.4** and **Figure 5.5**.

<u>Noise Contour of Construction Activities in Jetty area</u>

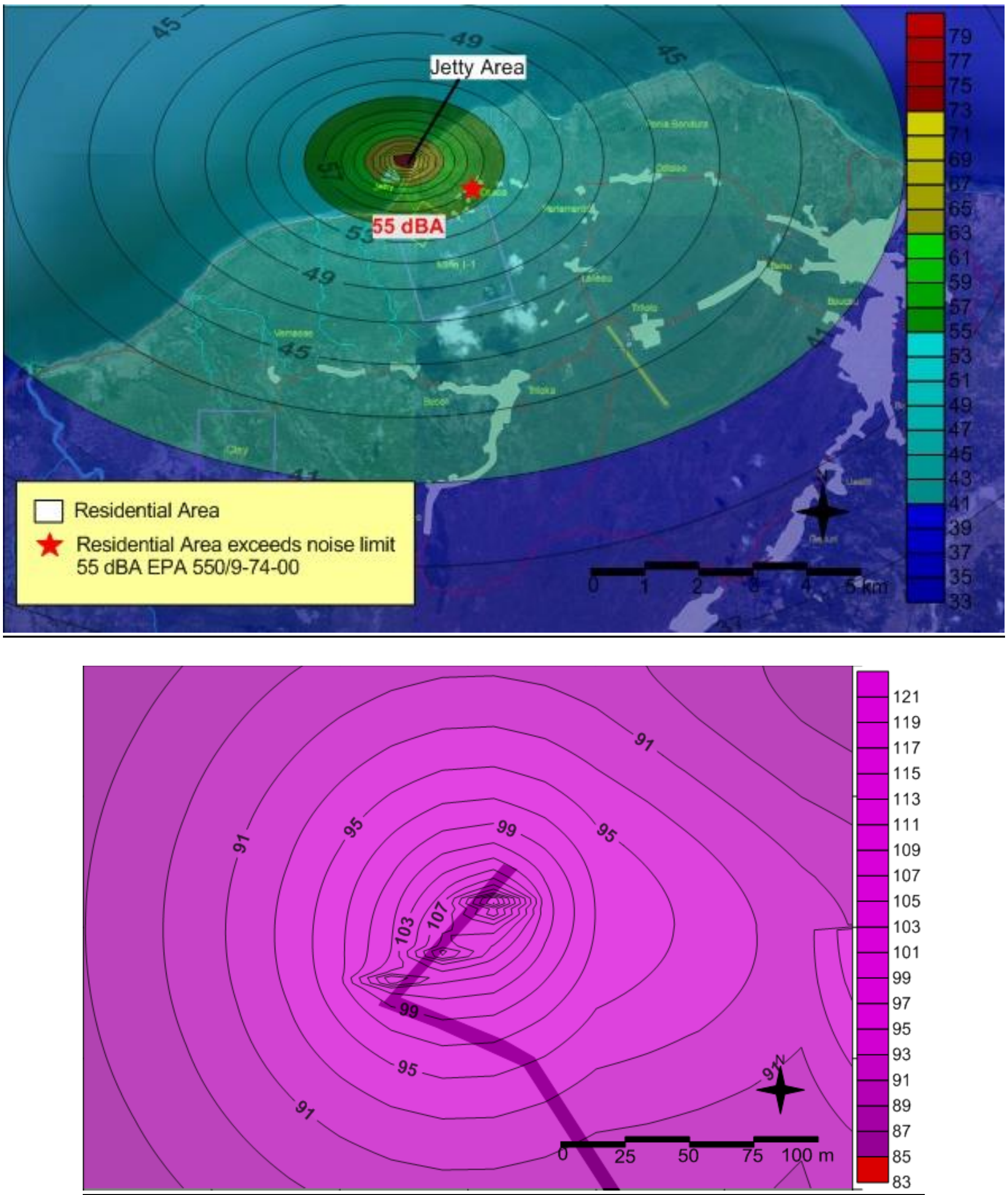


Figure 5.1 Noise contour of construction activities in Jetty area (in DBA)

Figure 5.1 is predicted noise level due to construction activity in the jetty area. This contour is on the certain height, which is 1.5 meters from the ground. It is based on the standard measurement used during baseline measurement. From **Figure 5.1** it can be seen that there is a residential area affected by noise from construction in the Jetty area, namely in Osso-ua, exceeds noise limit EPA 550/9-74-004 in residential area (55 dBA).

Noise Contour of Construction Activities in Plant area

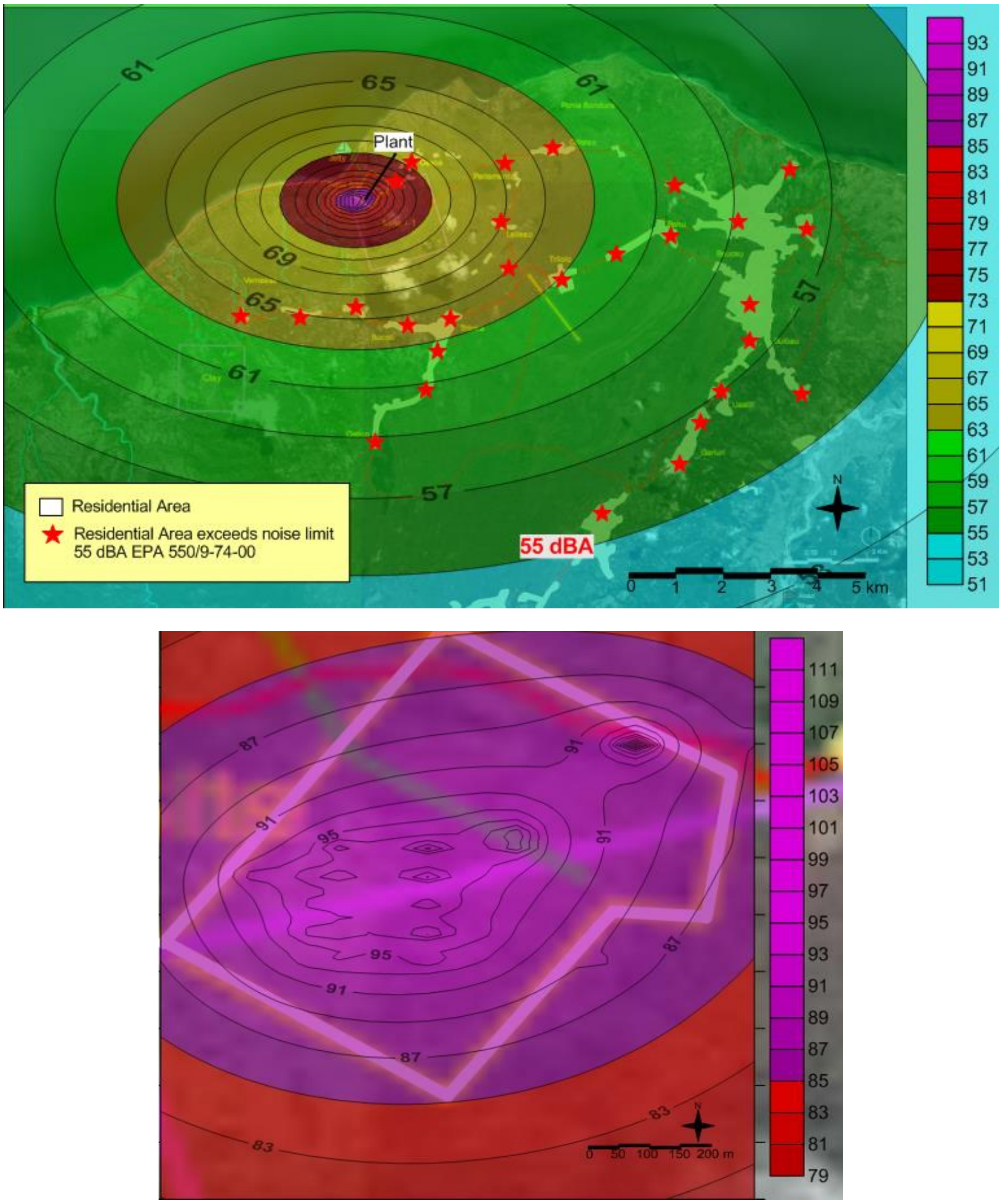
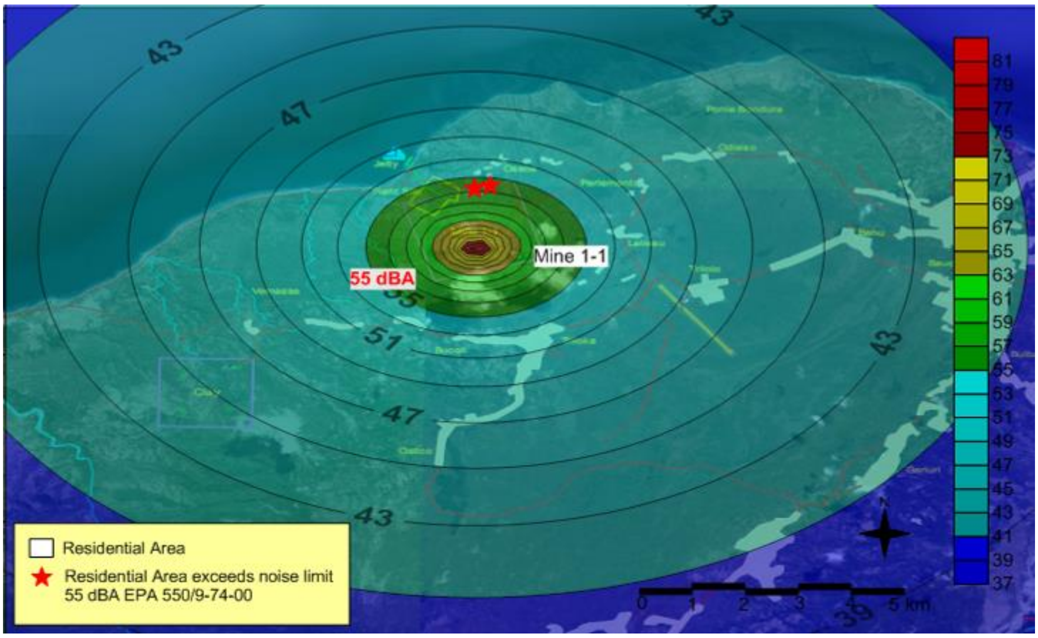


Figure 5.2 Noise contour of construction activities in Plant area (in DBA)

Figure 5.2 is predicted noise level due to construction activity in the Plant area. This contour is on the certain height, which is 1.5 meters from the ground. **Figure 5.2** showed that there are residential areas affected by noise from construction in the Plant area, namely Osso-ua, Parlemento, Caisido, Lialailesu, Vemasse, Bucoli, Ostico, Tirilolo ,Bahu, Baucau, Buibau, Ualili, and partly Garluri. The impact of noise in the area exceeds noise limit EPA 550/9-74-004 in residential area (55 dBA). Sensitive receptors which may experience higher noise impact than other receptors are located in Osso-ua.

Noise Contour of Construction Activities in Limestone Mine area



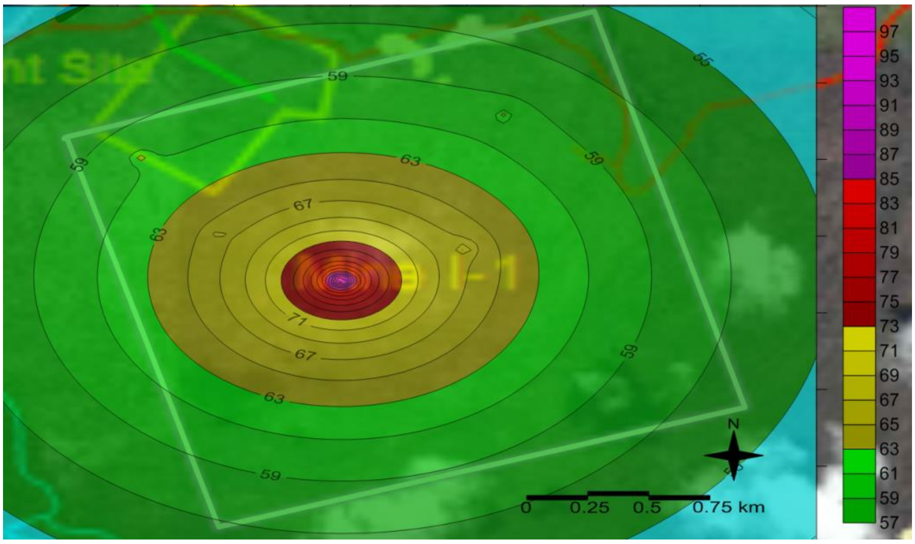


Fig 5.3 Noise contour of construction activities in Limestone Mine area (in DBA)

Figure 5.3 is predicted noise level due to construction activity in the Limestone mine area. This contour is on the certain height, which is 1.5 meters from the ground. There is a residential area affected by noise from construction activity in the mine areas, namely Osso-ua. The impact of noise in the area exceeds noise limit EPA 550/9-74-004 in residential area (55 dBA).

Noise Contour of Construction Activities in Clay area

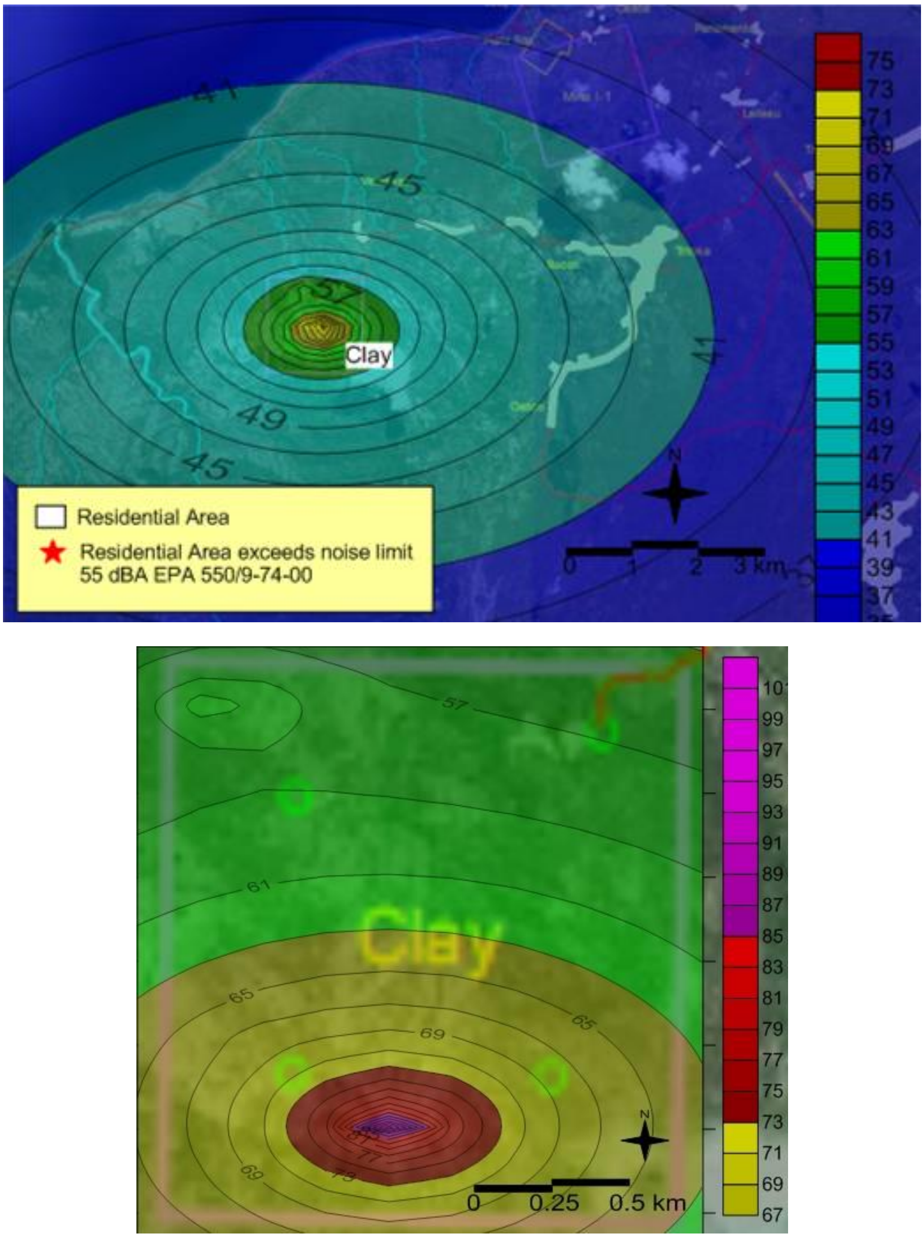


Figure 5.4 Noise contour of construction activities in Clay area (in DBA)

Figure 5.4 is predicted noise level due to construction activity in Clay area. This contour is on the certain height, which is 1.5 meters from the ground. There is no residential area affected by noise from construction activity in the clay areas.

Noise Contour of Construction Activities in Jetty, Plant, Limestone, and Clay area

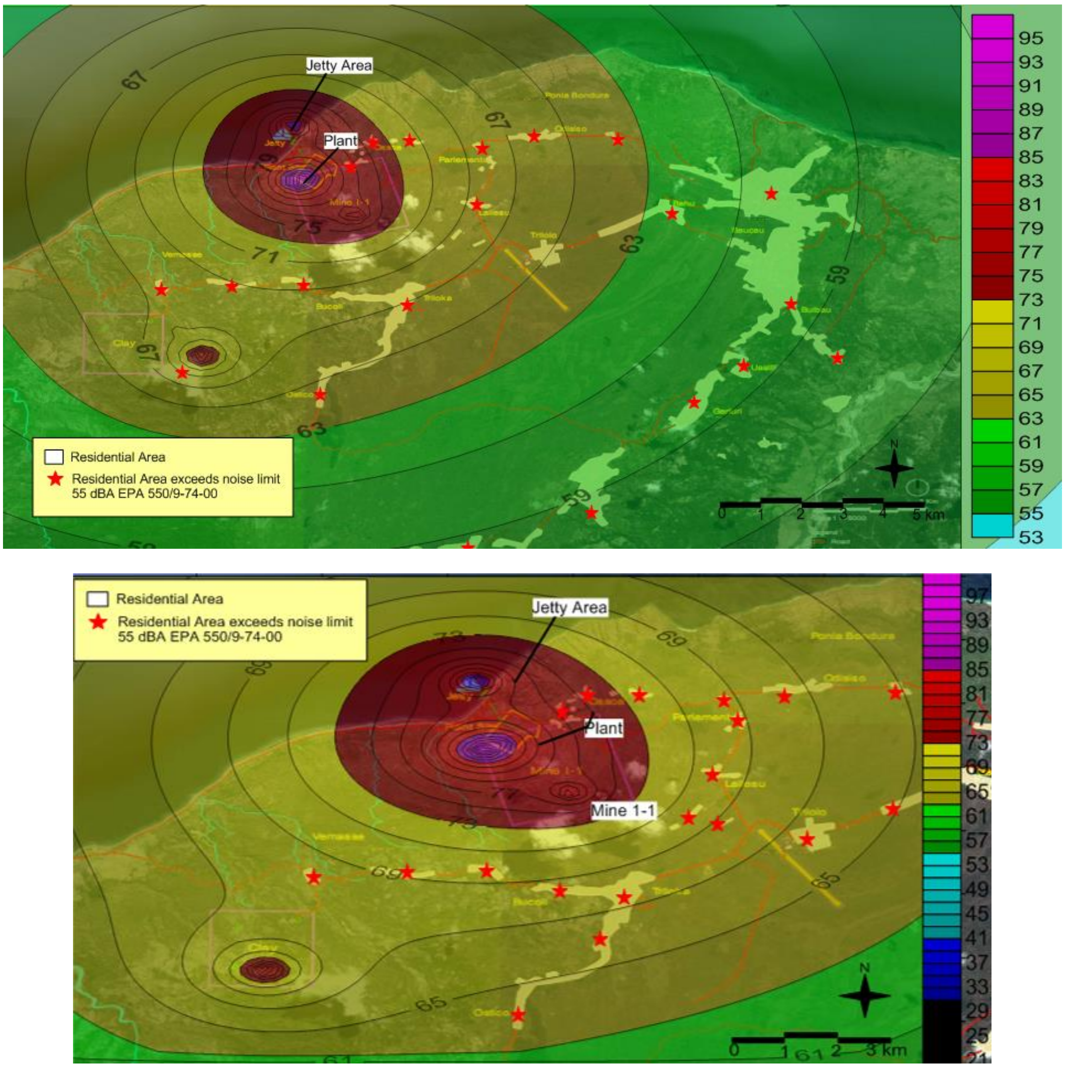


Figure 5.5 Noise contour of construction activities in Plant, Jetty, Limestone, and Clay areas (in DBA)

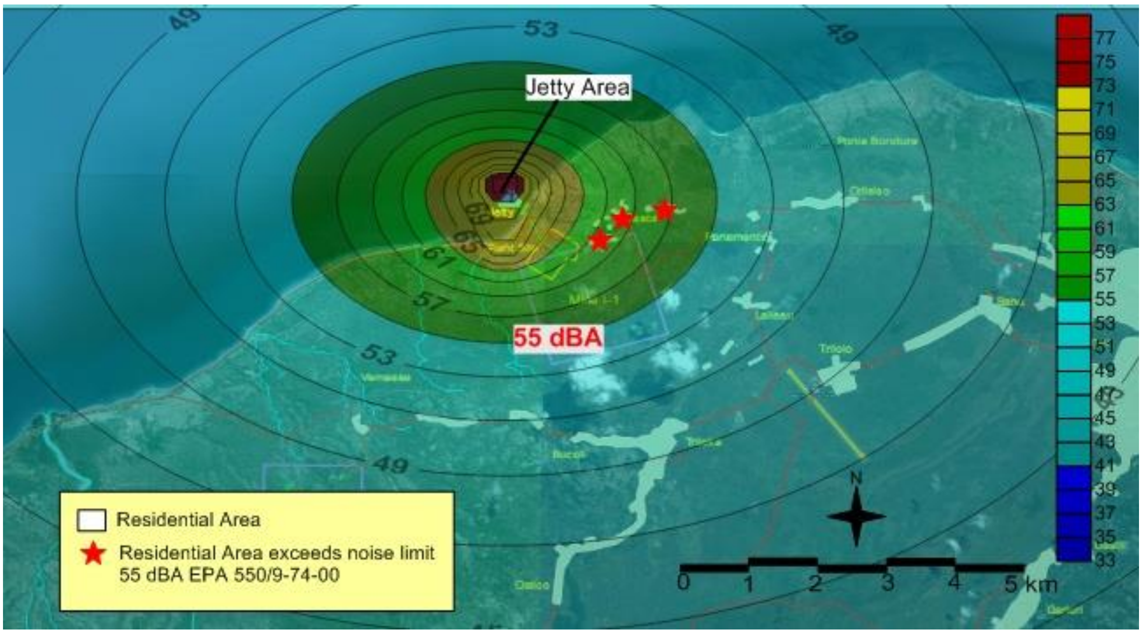
Figure 5.5 is predicted noise level due to simultaneous construction activity in the Plant, Jetty, Limestone, and Clay areas. This contour is on the certain height, which is 1.5 meters from the ground. There are residential areas affected by noise from construction activity in the Plant and Jetty areas, namely Osso-ua, Parlemento, Caisido, Lialailesu, Vemasse, Bucoli, Ostico, Tirilolo, Bahu, Buibau, Ualili, and Garluri. The impact of noise in the area exceeds noise limit EPA 550/9-74-004 in residential area (55 dBA).Sensitive receptors which may experience higher noise impact than other receptors are located in Osso-ua.

5.2 Operation Phase

Modeling noise contours during operation phase are shown in **Figure 5.6**, **Figure 5.7**, **Figure 5.8**, **Figure 5.9**, **Figure 5.10** and **Figure 5.11**.

Noise Contour of Operation Activities in Jetty area (in DBA)

Figure 5.6 is predicted noise level due to operation activities in the jetty area. This contour is on the certain height, which is 1.5 meters from the ground. **Figure 5.6** showed that there is a residential area affected by noise from the operation in the Jetty area, namely in Osso-ua. The impact of noise in the area exceeds noise limit EPA 550/9-74-004 in residential area (55 dBA). Sensitive receptors which may experience higher noise impact than other receptors are located in Osso-ua. The highest noise level is around 81 dBA.



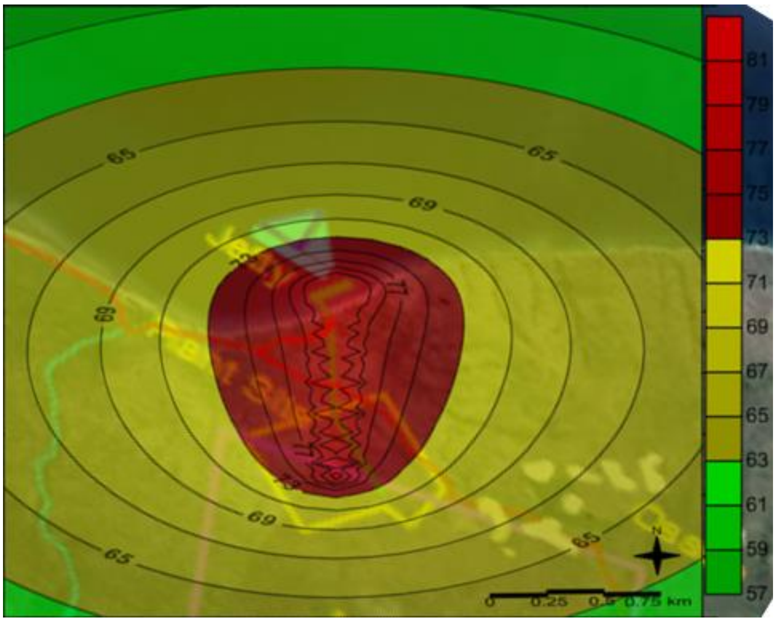


Figure 5.6 Noise contour of operation activities in Jetty area (in DBA)

Noise Contour of Operation Activities in Plant area

Figure 5.7 is predicted noise level caused by the operation activity in the Plant area. This contour is on the certain height, which is 1.5 meters from the ground. **Figure 5.7** showed that some residential area is affected by noise from the operation in the Plant area, namely Osso-ua, Parlemento, Caisido, Lialailesu, Vemasse, Bucoli, Ostico, Trilolo, Bahu, Buibau, Ualili, and partly Garluri. The impact of noise in the area exceeds noise limit EPA 550/9-74-004 in residential area (55 dBA). In addition, in the Plant area noise level due to the activities reaches more than 85 dBA. This exceeds the noise limit EPA 550/9-74-004 in industrial area (70 dBA). Sensitive receptors which may experience higher noise impact than other receptors are located in Osso-ua. The highest noise level is around 107 dBA.

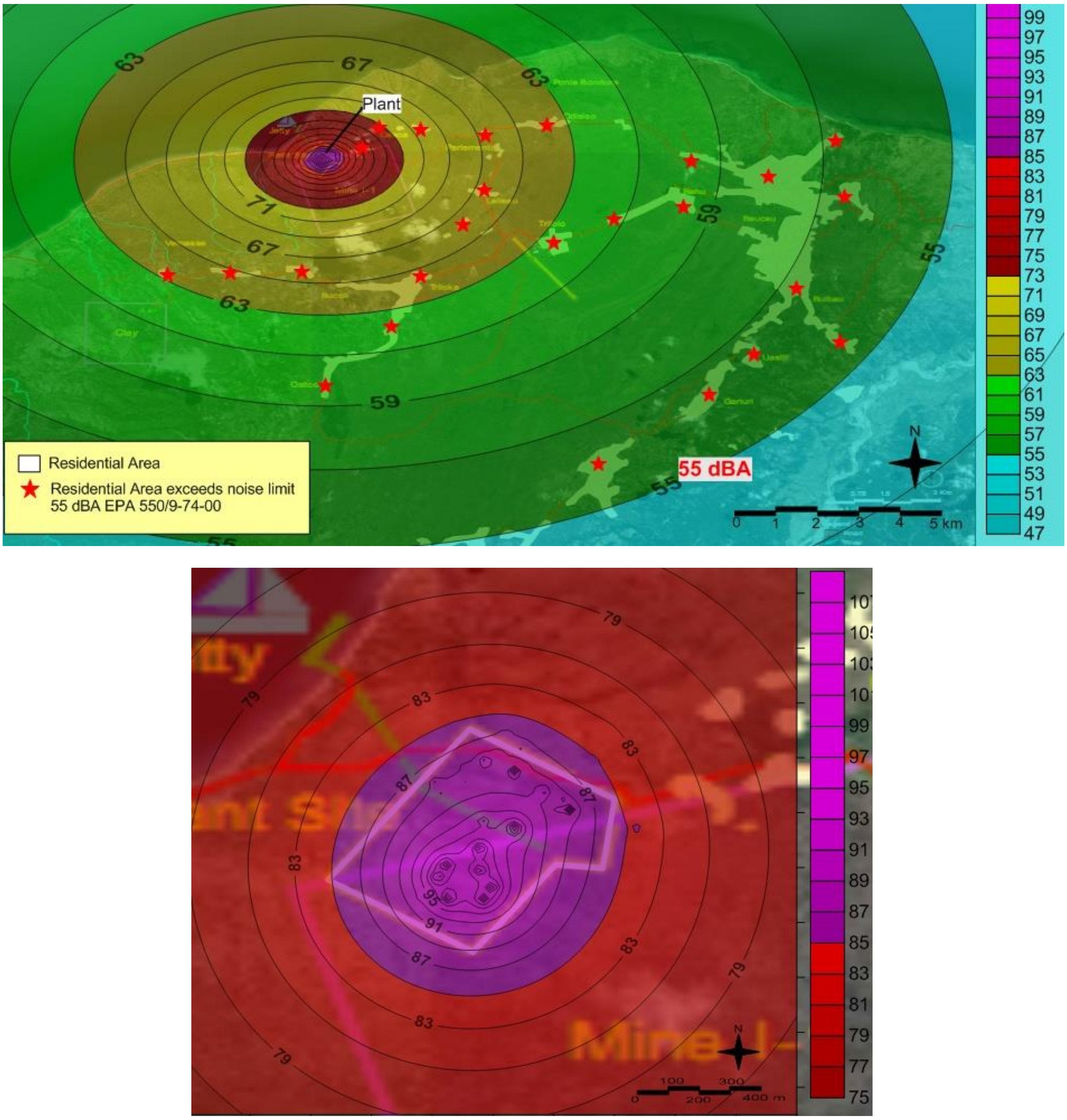


Figure 5.7 Noise contour of operation activities in Plant area (in DBA)

<u>Noise Contour of Operation Activities in Jetty and Plant area</u>

Figure 5.8 is predicted noise level caused by the operation activity in the Plant and Jetty area. This contour is on the certain height, which is 1.5 meters from the ground. **Figure 5.8** showed that some residential area is affected by noise from the operation in the Plant area, namely Osso-ua, Parlemento, Caisido, Lialailesu, Vemasse, Bucoli, Ostico, Tirilolo, Bahu, Buibau, Ualili, and Garluri. The impact of noise in the area exceeds noise limit EPA 550/9-74-004 in residential area (55 dBA). Sensitive receptors which may experience higher noise impact than other receptors are located in Osso-ua.

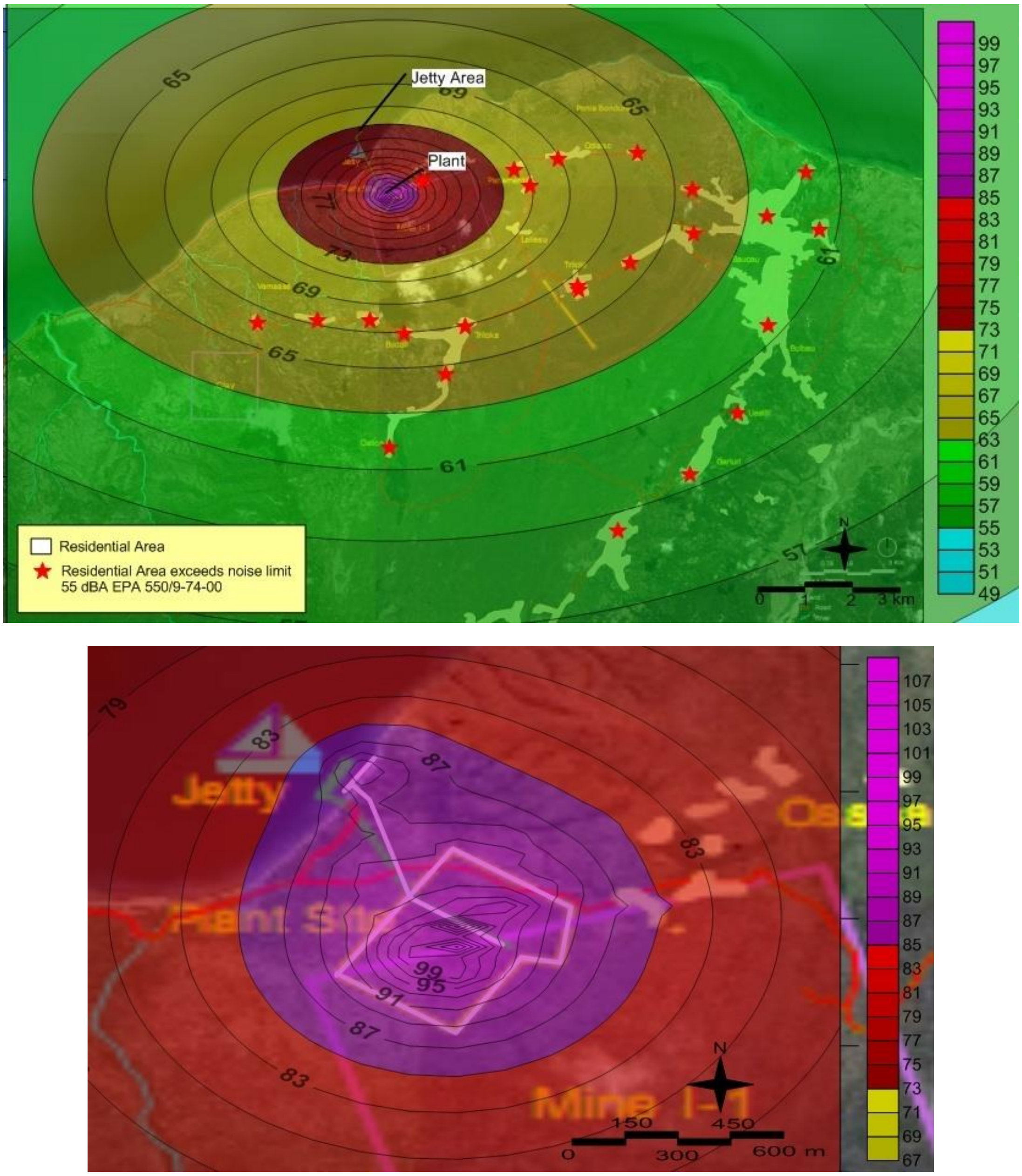


Figure 5.8 Noise contour of operation activities in Jetty and Plant area (in DBA)

<u>Noise Contour of Operation Activities in Mine 1-1 area</u>

Figure 5.9 is predicted noise level due to operation activities in the Mine 1-1 area. This contour is on the certain height, which is 1.5 meters from the ground. There are residential areas affected by noise from the operation in area Mine 1-1, which Osso-ua, Parlemento, Caisido, Lialailesu, Vemasse, Bucoli, and Tirilolo. The impact of noise in the area exceeds noise limit EPA 550/9-74-004 in residential area (55 dBA). In the Mine 1-1 area, the noise caused by the activities is below 65 dBA. This value meets the noise limit EPA 550/9-74-004 in industrial area (70 dBA). Sensitive receptors which may experience higher noise impact than other receptors are located in Osso-ua. The highest noise level is around 97 dBA.

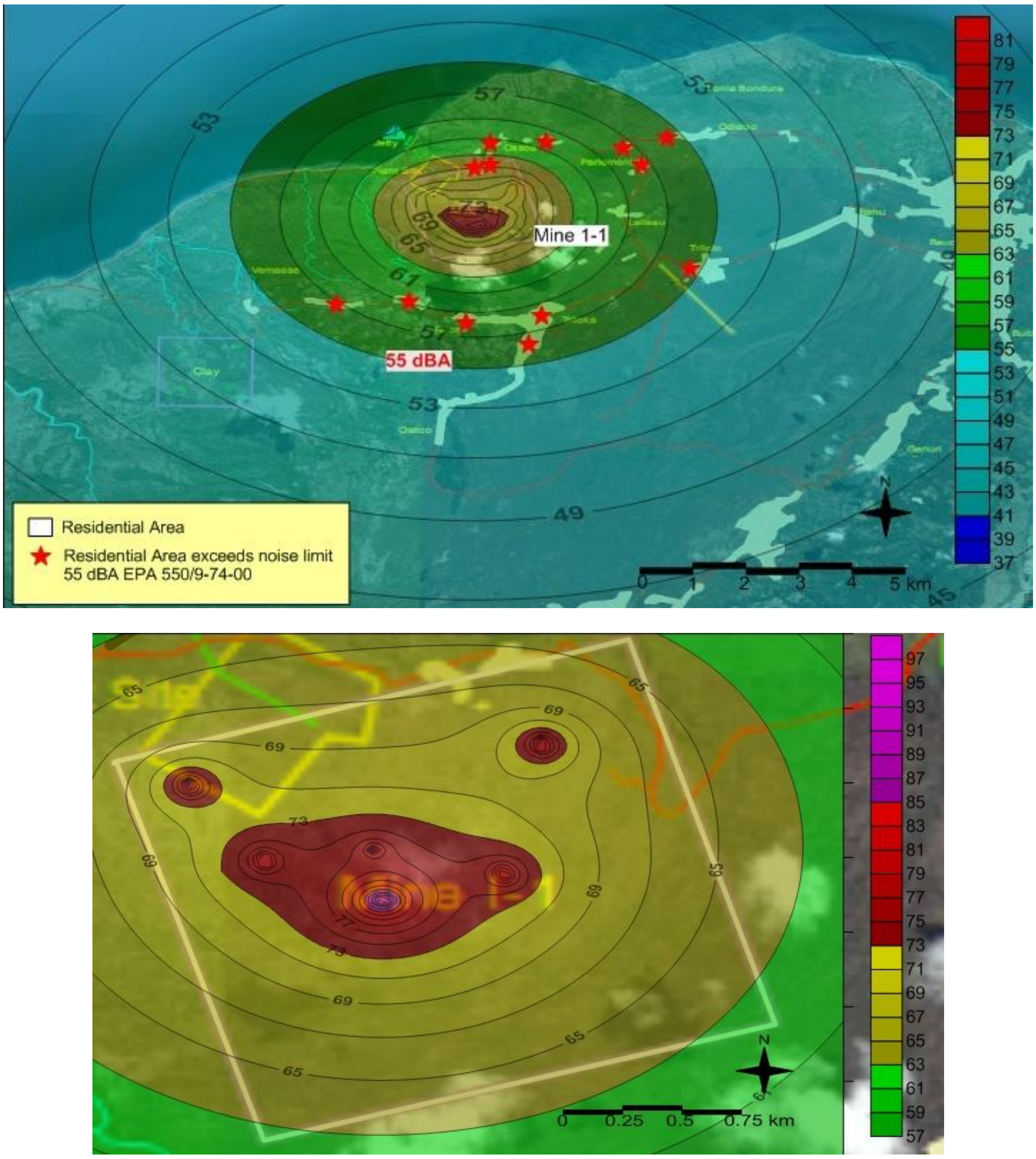


Figure 5.9 Noise contour of operation activities in Mine 1-1 area (in DBA)

<u>**Noise Contour of Operation Activities in Clay area**</u>

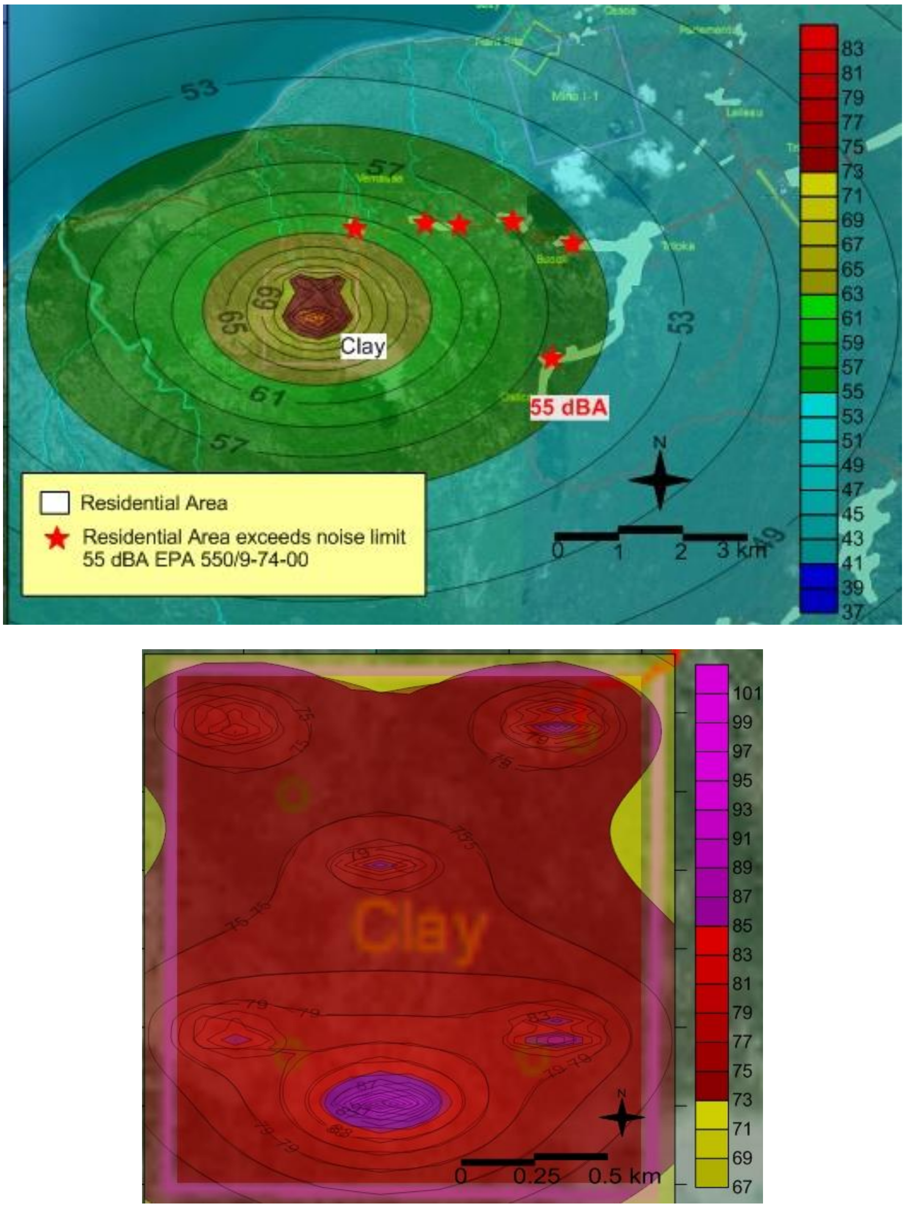


Figure 5.10 Noise contour of operation activities in Clay area (in DBA)

Figure 5.10 is predicted noise level due to operation activities in the Clay area. This contour is on the certain height, which is 1.5 meters from the ground. Some residential areas are affected by noise from the operation in the area of Clay, namely Wailacama, Vemasse, Bucoli, and Ostico. The impact of noise in the area exceeds noise limit EPA 550/9-74-004 in residential area (55 dBA). In addition, in the clay area, noise level due to the activities reaches 75 dBA. This exceeds the noise limit EPA 550/9-74-004 in industrial area (70 dBA) by 5 dBA. Sensitive receptors which may experience higher noise impact than other receptors are located in Wailacama. The highest noise level is around 101 dBA.

Noise Contour of Operation Activities in Jetty, Plant, Clay, and Mine 1-1 area

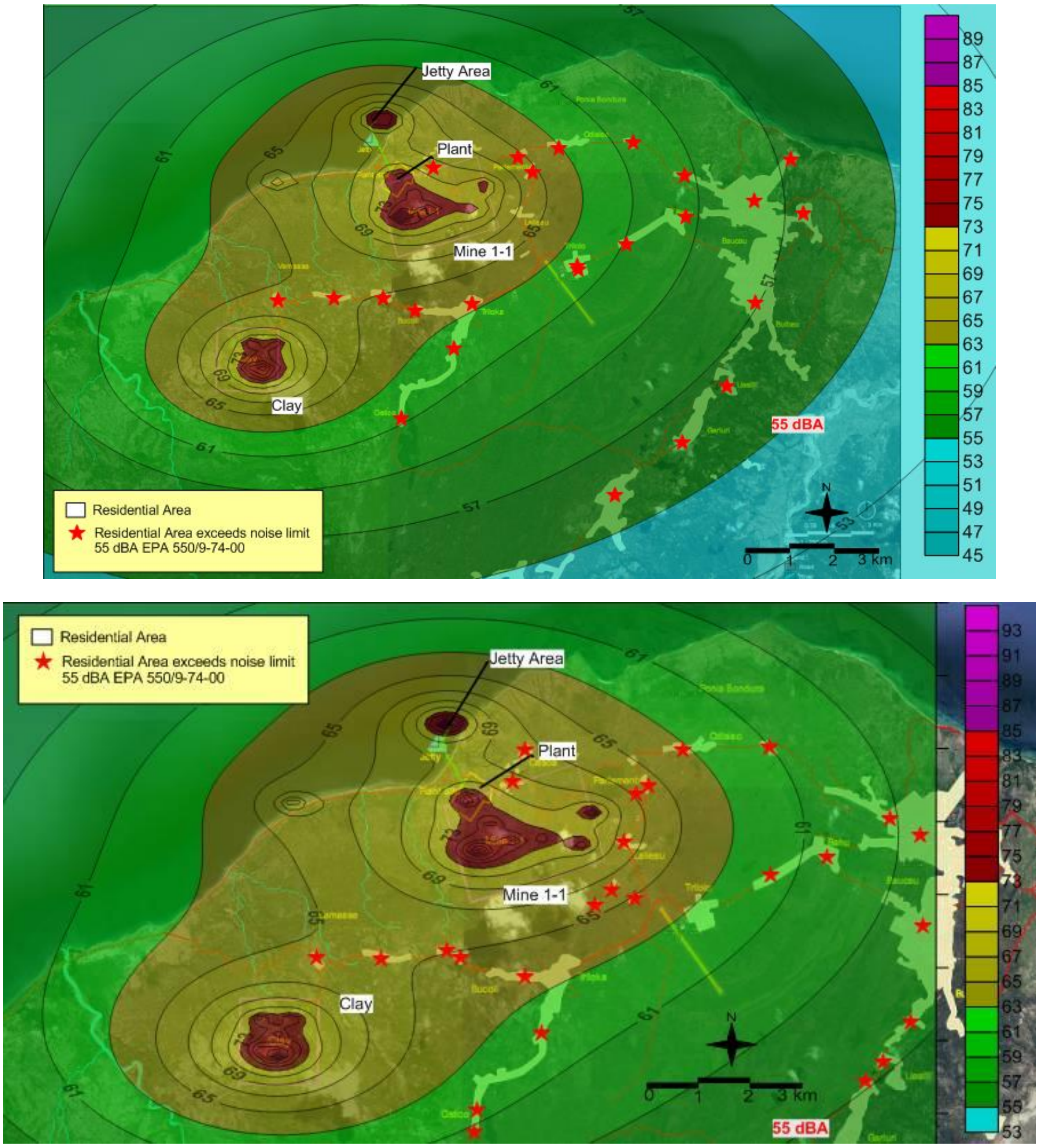


Figure 5.11 Noise contour of operation activities in Jetty, Plant, Clay, and Mine 1-1 area (in DBA)

Figure 5.11 is predicted noise level due to operation activities simultaneously at the jetty, plant, mine 1-1, and clay areas. This contour is on the certain height, which is 1.5 meters from the ground. There are residential areas affected by noise from simultaneous operation activities, namely Osso-ua, Parlemento, Caisido, Lialailesu, Vemasse, Bucoli, Wailacama, Ostico, Trilolo, Bahu, Buibau, Ualili, and Garluri. The impact of noise in the area exceeds noise limit EPA 550/9-74-004 in residential area (55 dBA). Sensitive receptors which may experience higher noise impact than other receptors are located in Osso-ua.

5.3 Sensitivity Analysis

5.3.1 Construction Phase

Table 5.1 Predicted Noise Level during Construction Phase in Sensitive Receptors Points

Receptor Points	Noise Baseline (dBA)	Predicted Noise Level during Construction Phase (dBA)	Δ ($L_{baseline}$ - $L_{predicted}$)(dBA)	Note
N01	56.27	64	8	Exceed noise limit EPA 550/9-74-004 by 9 dBA
N02	55.52	67	12	Exceed noise limit EPA 550/9-74-004 by 12 dBA
N03	50.20	68	18	Exceed noise limit EPA 550/9-74-004 by 13 dBA
N04	54.83	74	19	Exceed noise limit EPA 550/9-74-004 by 19 dBA
N05	51.92	81	29	Exceed noise limit EPA 550/9-74-004 by 26 dBA
N06	46.34	68	22	Exceed noise limit EPA 550/9-74-004 by 13 dBA
N07	50.71	69	19	Exceed noise limit EPA 550/9-74-004 by 14 dBA

During the construction phase, predicted noise level in seven sensitive receptors points exceeds the noise limit EPA 550/9-74-004. In N01, predicted noise level during construction is 64 dBA, it exceeds the noise limit EPA 550/9-74-004 by 9 dBA. In N02, predicted noise level during construction is 67 dBA, it exceeds the noise limit EPA 550/9-74-004 by 12 dBA. In N03 and N06, predicted noise level during construction is 68 dBA, it exceeds the noise limit EPA 550/9-74-004 by 13 dBA. In N04, predicted noise level during construction is 74 dBA, it exceeds the noise limit EPA 550/9-74-004 by 19 dBA. In N05, predicted noise level during construction is 81 dBA, it exceeds the noise limit EPA 550/9-74-004 by 26 dBA. In N07, predicted noise level during construction is 69 dBA, it exceeds the noise limit EPA 550/9-74-004 by 14 dBA.

From **Figure 5.12**, it can be seen that during construction phase in the jetty area, noise criteria for residential area is achieved at a distance of approximately 2,000 meters (2 km) from noise source. During construction phase in the plant area with activities that involve more equipment, noise criteria for residential areas is not yet achieved at a distance of 5,000 meters (5 km) from noise source. While during construction phase in clay area, noise criteria for residential area is achieved at a distance of approximately 1,000 meters (1 km) from noise source. During construction phase in the limestone mine area, noise criteria for residential area is achieved at a distance of approximately 2,500 meters (2.5 km) from noise source. While during construction phase in the plant, jetty, clay, and limestone mine area, noise criteria for residential is not yet achieved at a distance of 5,000 meters (5 km). Beyond 5 km, there may be other existing dominant noise in the local area.

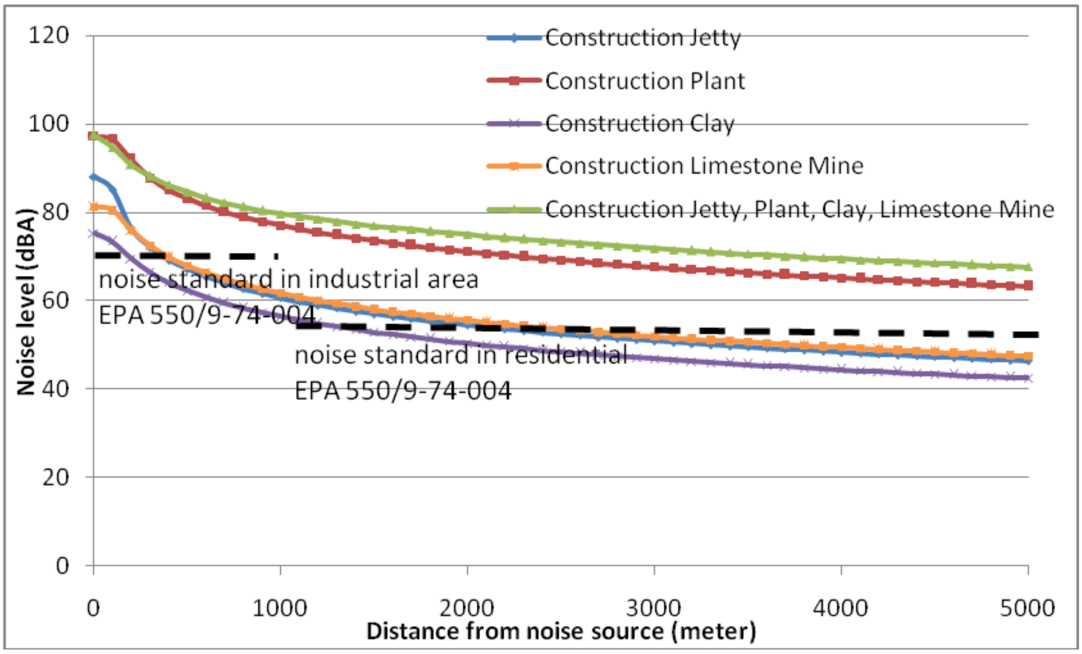


Figure 5.12 The decrease of sound pressure level to the distance from the noise source in construction

5.3.2 Operation Phase

Table 5.2 Predicted Noise Level during Operation Phase in Sensitive Receptors Points

Receptor Points	Noise Baseline (dBA)	Predicted Noise Level during Operation Phase (dBA)	Δ ($L_{baseline}$ - $L_{predicted}$)(dBA)	Note
N01	56.27	56	0	
N02	55.52	61	6	Exceed noise limit EPA 550/9-74-004 by 6dBA
N03	50.20	62	12	Exceed noise limit EPA 550/9-74-004 by 7dBA
N04	54.83	68	15	Exceed noise limit EPA 550/9-74-004 by 13dBA
N05	51.92	73	21	Exceed noise limit EPA 550/9-74-004 by 18dBA
N06	46.34	60	14	Exceed noise limit EPA 550/9-74-004 by 4dBA
N07	50.71	63	14	Exceed noise limit EPA 550/9-74-004 by 7dBA

During the operation phase, predicted noise level in six sensitive receptors points exceeds the noise limit EPA 550/9-74-004. In N01, predicted noise level during operation is 56 dBA. The value is in allowable level of the noise limit EPA 550/9-74-004 with 3 dB tolerance. In N02, predicted noise level during operation is 61 dBA, it exceeds the noise limit EPA 550/9-74-004 by 6 dBA. In N03, predicted noise level during operation is 62 dBA, it exceeds the noise limit EPA 550/9-74-004 by 7 dBA. In N04, predicted noise level during operation is 68 dBA, it exceeds the noise limit EPA 550/9-74-004 by 13 dBA. In N05, predicted noise level during operation is 73 dBA, it exceeds the noise limit EPA 550/9-74-004 by 18 dBA. In N06, predicted noise level during operation is 60 dBA, it exceeds the noise limit EPA 550/9-74-004 by 4 dBA. In N07, predicted noise level during operation is 63 dBA, it exceeds the noise limit EPA 550/9-74-004 by 7 dBA.

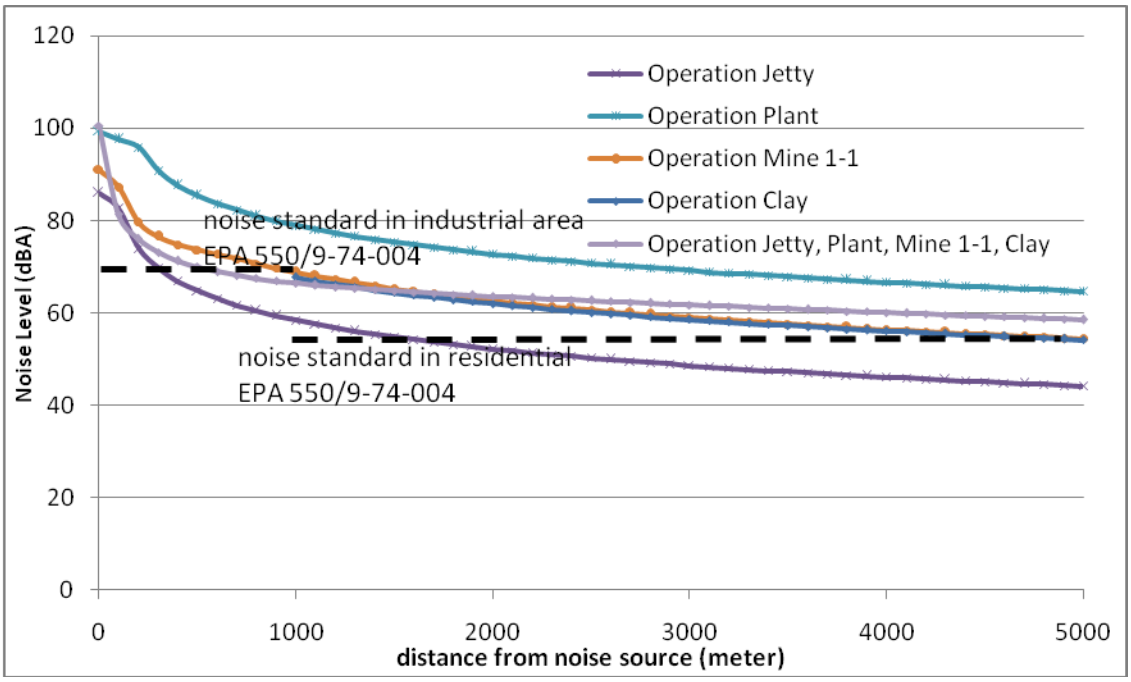


Figure 5.13 The decrease of sound pressure level to the distance from the noise source in operation activities

From **Figure 5.13**, it can be seen that during operation phase at the jetty area, noise criteria for residential area is achieved at a distance of approximately 1,500 meters (1.5 km) from the source. During operation phase in the plant area, noise criteria for residential area is not yet achieved at a distance of approximately 5,000 meters (5 km) from the source. During operation phase in Mine 1-1 area with more noise source, noise criteria for residential area is achieved at a distance of approximately 4,500 meters (4.5 km) from the source. During operation phase in Clay area, noise criteria for residential area is achieved at a distance of approximately 4,500 meters (4.5 km) from the source. While during operation phase in the jetty area, plant, clay, and Mine 1-1, noise criteria for residential area is not yet achieved at a distance of 5,000 meters (5 km) from the source. Beyond 5 km, there may be other existing dominant noise in the local area.

6. IMPACT MITIGATION

Table 6.1 Sound attenuation to meet noise limit EPA 550/9-74-004 during construction and operation

Receptor Points	Sound Attenuation to meet noise limit EPA 550/9-74-004 during Construction (dBA)	Sound Attenuation to meet noise limit EPA 550/9-74-004 during Operation (dBA)
N01	9	6
N02	12	7
N03	13	13
N04	19	18
N05	26	4
N06	13	7
N07	14	6

The cement plant project will have negative impacts to the noise ambience level, not only during construction but also during operation phase. The impact is indicated by the increase of noise level. Impact assessment has shown that the noise level generally will have increase in TL Cement area. Furthermore, in residential areas it even exceeds the noise limit exceeds the noise limit EPA 550/9-74-004 (55 dBA) by 4 to 26 dBA (**Table 6.1**). Therefore, mitigation must be implemented to keep the noise level in residential areas is in allowable level. Mitigation is intentionally to increase the attenuation of sound level from noise sources to receptors.

To reduce the impact of noise both in the construction and the operation phase, there are mitigation options as follows:

1. **Design Options**

Noise impacts can occur during the construction and operation phase. While the magnitude of the impact construction noise may have on a community may not be known early in the project development stages, measures can be implemented during the design phase that can help to reduce the anticipated noise impacts at sensitive receptors. However, design changes and modification to project layout are not always practical or feasible.

a. Design and Project Layout

In addressing construction noise mitigation during the design phases of a project, abatement opportunities can be considered for a variety of areas and features including those listed below:

- **Storage Areas**: During the planning and design stages of a project, storage areas may be able to be designated in locations removed from sensitive receptors. Where this is not possible, the storage of waste materials, earth, and other supplies may be able to be positioned in a manner that will function as a noise barrier.

- **Haul Roads:** Haul roads can be designated in locations where the noise impacts caused by truck traffic will be reduced.
- **Existing Barriers:** As early as possible in the design development process, natural and artificial barriers such as ground elevation changes, existing buildings, noise walls, and other structures can be considered for use as a noise shield during certain operations.

b. Sequence of Operations

The sequencing and scheduling of construction or operation is equally important in addressing and mitigating noise:

- **Concurrent Operations:** It may be possible to schedule several noisy operations concurrently to take advantage of the fact that the combined noise levels produced may not be significantly greater than the level produced if the operations were performed separately.
- **Early Construction of Noise Barriers:** Ultimately, noise barriers that are to be constructed as part of the project for traffic noise abatement can possibly be installed during the initial stages of construction to reduce the noise impacts of the construction.

c. Alternative Construction Methods

Alternatives to standard construction techniques may also be available and determined to be more practical and/or cost-effective in dealing with construction noise impacts and perceptions. Examples associated with several operations are;

- **Pile Driving:** Pile driving may produce noise levels in excess of acceptable limits, even when feasible noise reduction methods are used. Various dampening and shielding methods discussed later can attain some reduction. However, such methods rarely reduce the noise level to an acceptable level for the sensitive receptors close to the site. As an alternative to driving piles, it is possible to use vibration or hydraulic insertion techniques. Drilled or augured holes for cast-in-place piles are another alternative that may produce noise levels significantly lower than the traditional driving method.
- **Compressors:** While most compressors are powered by diesel or gasoline engines, many are contained or have baffles to help abate noise levels. Electric compressors are significantly quieter than diesel or gasoline engine powered compressors.

2. **Mitigation at the Source**

Source control is, in general, the most effective form of noise mitigation and involves controlling a noise source before it is able to emit potentially offensive noise levels. Construction noise (exclusive of blasting) is typically generated by two source types, which are stationary equipment; and mobile equipment. Noise levels from both types of noise sources are dependent on equipment characteristics and their operation.

a. All types equipment

- **less noisy equipment**: One of the most effective methods of diminishing the noise impacts caused by individual equipment is to use less noisy machinery. By specifying and/or using less noisy equipment, the impacts produced can be reduced or, in some cases, eliminated. Source control requirements may have the added benefits of promoting technological advances in the development of quieter equipment.

- **Mufflers:** Most construction noise originates from internal combustion engines. A large part of the noise emitted is due to the air intake and exhaust cycle. Specifying the use of adequate muffler systems can control much of this engine noise.
- **Shields**: Employing shields that are physically attached to the particular piece of equipment is effective, particularly for stationary equipment and where considerable noise reduction is required.
- **Dampeners**: Equipment modifications, such as dampening of metal surfaces, is effective in reducing noise due to vibration. Another possibility is the redesign of a particular piece of equipment to achieve quieter noise levels
- **Aprons:** Sound aprons generally take the form of sound absorptive mats hung from the equipment or on frames attached to the equipment. The aprons can be constructed of rubber, lead-filled fabric, or PVC layers with possibly sound absorptive material covering the side facing the machine. Sound aprons are useful when the shielding must be frequently removed or if only partial covering is possible.
- **Enclosures:** Enclosures for stationary work may be constructed of wood or any other suitable material and typically surround the specific operation area and equipment. The walls could be lined with sound absorptive material to prevent an increase of sound levels within the structure. They should be designed for ease of erection and dismantling.
- **Blasting Mats:** These mats are typically made with layers of used tires cabled together. They are commonly used as blankets for blasting operations to control and confine debris. These mats also provide a degree of noise attenuation from the blast. However, they do not mitigate vibration, which is usually more of a concern than noise.
- **Selection of Equipment:** Newer equipment is generally quieter than old equipment for many reasons, including technological advancements and the lack of worn, loose, or damaged components. Some equipment manufacturers have made their equipment quieter in recent years and have achieved significant reductions over older equipment. In some cases, the use of over- or under-powered equipment may be an unexpected source of excessive noise. The types of engines and power transfer methods also plays a significant roll in achieving lowered equipment noise. The use of electric powered equipment is typically quieter than diesel, and hydraulic powered equipment is quieter than pneumatic power.
- **Maitenance Programs**: Poor maintenance of equipment typically causes excessive noise levels. Faulty or damaged mufflers and loose engine parts such as screws, bolts, or metal plates contribute to increased noise levels. Removal of noise-reducing attachments and devices such as mufflers, silencers, covers, guards, vibration isolators, etc., will to varying degrees, increase noise emission levels. Old equipment may be made quieter by simple modifications, such as adding new mufflers or sound absorbing materials. Loose and worn parts should be fixed as soon as possible.

b. Stationary Equipment

Whenever possible, positioning stationary noise sources as far away as possible from noise sensitive areas should be considered. Temporary barriers can be employed and/or enclosures can be built around noisy equipment. These techniques can significantly reduce noise levels and, in many cases, are relatively inexpensive. These barriers can typically be constructed on the work site from common construction building material (plywood, block, stacks, or spoils). Enclosures are often constructed from commercial panels lined with sound absorbing material to achieve the maximum possible shielding effect.In addition, providing increased distance between a noise source and a noise receiver can also be considered a form of abatement.

c. Mobile Equipment

Many construction operations are mobile and tend to progress along the length of a project at varying rates. Noise levels at the receiver tend to vary considerably, not only as the speed and power of the equipment varies, but also as the equipment is constantly changing in terms of its distance from the receivers and its relative location. Enclosing mobile equipment is usually not possible, unless the operation is slow moving and the enclosures can be easily moved.

3. **Mitigation Along the Path**

In some situations, such as in urban areas or on isolated sections of a project, it may be beneficial and necessary to construct barriers adjacent to the work area or at the right-of-way. These can take the form of natural shielding, temporary shielding, and/or permanent shielding. The types of barriers are:

a. Natural Shielding

b. Temporary Shielding

c. Permanent Shielding

4. **Mitigation at the Receiver**

Mitigation at a receiver can vary in its complexity, ranging anywhere from relocating residents for a day to insulation of a building. Even after mitigation measures have been applied, the outcome may still be unpredictable with no guarantees that the implemented methods achieve expected results. Therefore, mitigation at the receiver should only be considered as a last alternative.

a. Building Envelope Improvements

Building envelope mitigation to reduce noise can include techniques such as sealing existing building elements, providing new sealed windows and doors, adding building insulation, etc. Such techniques, while effective, may also require modification of the building's heating, ventilation, and air conditioning system. Prior to proposing such treatments, thorough consideration of the costs and implications of such modifications is suggested.

b. Masking

Noise masking is a technique that is still in the developmental stage but may have potential in isolated cases. Masking considerations could include techniques such as constructing water falls or other cascading water designs, employment of noise cancellation technologies, changing "background" noise levels, etc. Such techniques require a consideration of the type of noise generator (stationary, mobile, etc.), the source's noise frequency content, variability of the noise source in terms of its magnitude and duration, and the noise environment of the receptor being protected.

7. CONCLUSION

With a view to expand cement manufacturing business, a new company TL Cement LDA (TLC) has been established at Baucau in Timor-Leste. In the construction and operational phases, heavy equipment used will become a new source of noise in the area TL Cement. During the development, noise emission will occur continuously, therefore it is necessary to model the noise dispersion with the aim to predict the distribution of noise caused by activities and actions during construction and operations phase in TL Cement. To obtain reliable noise prediction results, a study on the effects of noise distribution is done using software that has been widely used, MATLAB® with reference to ISO 9613, the Attenuation of Sound during Propagation Outdoors. Theresults from Matlab is then plotted using Surfer software.

During the construction phase, predicted noise level in seven sensitive receptors points exceeds the noise limit EPA 550/9-74-004. In N01, predicted noise level during construction is 64 dBA, it exceeds the noise limit EPA 550/9-74-004 by 9 dBA. In N02, predicted noise level during construction is 67 dBA, it exceeds the noise limit EPA 550/9-74-004 by 12 dBA. In N03 and N06, predicted noise level during construction is 68 dBA, it exceeds the noise limit EPA 550/9-74-004 by 13 dBA. In N04, predicted noise level during construction is 74 dBA, it exceeds the noise limit EPA 550/9-74-004 by 19 dBA. In N05, predicted noise level during construction is 81 dBA, it exceeds the noise limit EPA 550/9-74-004 by 26 dBA. In N07, predicted noise level during construction is 69 dBA, it exceeds the noise limit EPA 550/9-74-004 by 14 dBA.

Modeling result shows that during construction phase in the jetty area, noise criteria for residential area is achieved at a distance of approximately 2,000 meters (2 km) from noise source. During construction phase in the plant area with activities that involve more equipment, noise criteria for residential areas is not yet achieved at a distance of 5,000 meters (5 km) from noise source. Beyond 5 km, there may be other existing dominant noise in the local area.

During the operation phase, predicted noise level in six sensitive receptors points exceeds the noise limit EPA 550/9-74-004. In N01, predicted noise level during operation is 56 dBA. The value is in allowable level of the noise limit EPA 550/9-74-004 with 3 dB tolerance. In N02, predicted noise level during operation is 61 dBA, it exceeds the noise limit EPA 550/9-74-004 by 6 dBA. In N03, predicted noise level during operation is 62 dBA, it exceeds the noise limit EPA 550/9-74-004 by 7 dBA. In N04, predicted noise level during operation is 68 dBA, it exceeds the noise limit EPA 550/9-74-004 by 13 dBA. In N05, predicted noise level during operation is 73 dBA, it exceeds the noise limit EPA 550/9-74-004 by 18 dBA. In N06, predicted noise level during operation is 60 dBA, it exceeds the noise limit EPA 550/9-74-004 by 4 dBA. In N07, predicted noise level during operation is 63 dBA, it exceeds the noise limit EPA 550/9-74-004 by 7 dBA.

During operation phase at the jetty area, noise criteria for residential area is achieved at a distance of approximately 1,500 meters (1.5 km) from the source. During operation phase in the plant area, noise criteria for residential area is not yet achieved at a distance of approximately 5,000 meters (5 km) from the source. During operation phase in Mine 1-1 area with more noise source, noise criteria for residential area is achieved at a distance of approximately 4,500 meters (4.5 km) from the source. During operation phase in Clay area, noise criteria for residential area is achieved at a distance of approximately 4,500 meters (4.5 km) from the source.While during operation phase in the jetty area, plant, clay, and Mine 1-1, noise criteria for residential area is not yet achieved at a distance of 5,000 meters (5 km) from the source.Beyond 5 km, there may be other existing dominant noise in the local area.

In general, modeling results indicate that the predicted impacts of TL Cement development have quite significant impact on the increase in noise levels in areas around TL Cement. Therefore, mitigation must be implemented to keep the noise level in residential areas is in allowable level. To reduce the impact of noise both in the construction and the operation phase, there are mitigation options like design options, mitigation at the source, mitigation along the path, and mitigation at the receptors.

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Appendix 3 Surface Water Impact Assessment Report

Advisian
WorleyParsons Group

TL Cement

Baucau Cement Project

Surface Water Impact Assessment Report

14-Dec-15

Advisian is a global advisory firm that provides project and business solutions to clients who develop, operate and maintain physical assets in the infrastructure and resources sectors.

Advisian Pty Ltd
Level 6, 600 Murray St
West Perth
WA 6005
Australia

P +61 8 9485 3811
F +61 8 9481 3118
ABN: 50098008818

www.advisian.com

Advisian
WorleyParsons Group

TL Cement
Baucau Cement Project
Surface Water Impact Assessment Report

Synopsis

Advisian were engaged by TL Cement to assess the potential surface water impacts associated with the Baucau Cement Project and to present surface water management measures needed to protect areas of social and ecological value that are dependent on surface water runoff. Specifically, the springs used for public water supply and Closed Tropical Forest vegetation and associated fauna species identified along the natural watercourses and drainage lines must be protected.

The results of this surface water assessment suggest the proposed developments associated with the Baucau Cement Project, with the recommended surface water management measures in place, are not expected to have a significant impact on the quantity and quality of streamflow or on the associated environmental receptors in the study area.

Although the presence of highly permeable karst limestone limits the volume of rainfall-runoff generated in the catchments areas, there is still some risk of flash flooding during extreme rainfall events. Therefore diversion drains and bunds are proposed in this report to divert floodwater around mine and plant areas. Further hydrological investigations are needed to design diversions and culvert-floodway crossings in the mine and plant areas.

Surface water quality management measures are proposed in this report to mitigate risk of contamination of spring water from surface water flowing off the plant and mine sites. Monitoring of surface water flows and water quality in watercourses and drainage lines is recommended to establish baseline conditions and for compliance monitoring.

PROJECT NO 301012-02135– BAUCAU CEMENT PROJECT: SURFACE WATER IMPACT ASSESSMENT REPORT

Rev	Description	Author	Review	Advisian Approval	Date
Rev 0	Issued for Use	S Atkinson	T Weaver	S Atkinson	17/02/15

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1 Introduction

1.1 Background

TL Cement LDA, a privately-owned company, proposes to construct a Greenfield cement manufacturing project in Baucau Municipality, Timor-Leste. The project will produce approximately 1.65 million tons per annum (mtpa) of Portland cement clinker. For the purposes of this EIS, the overall project will be referred to as the Baucau Cement Project. The project location is shown in Figure 1-1.

The limestone required for the proposed clinker plant is to be provided by mining the Bucoli limestone deposit. The limestone is to be transported via haul road to the cement plant site for processing. The cement product is then transported via conveyor to the marine jetty where it is loaded onto vessels for export. The location of the mine, cement plant, conveyor and jetty are shown in Figure 1-1.

The project will have four phases: Pre-construction (18 months), Construction (2 years), Operations (over 35 - 50 years) and Decommissioning (5 years). A summary of the activities to be undertaken during each phase are presented in Table 1-1.

The key project characteristics are listed in Table 1-2.

Figure 1-1: Project Location, Limestone Mine, Cement Plant, Conveyor and Jetty

Table 1-1: Summary of Baucau Cement Project phase characteristics

Phase	Activities
Pre-construction (Duration of approximately 18 months)	• Clearing of fence lines & Installing fences • Clearing for construction of access roads internal to the project area • Establishment of Laydown areas and preliminary office infrastructure such as portable toilets and shipping containers for storage • Relocation of people and animals from within the project area • Exploratory water source drilling and installation of water supply wells. • Installation of power supply infrastructure corridors via clearing, excavation and pegging • Geological studies including bore drilling and pit surveys • Monitoring weir installations in ephemeral watercourses to record flows and water quality. • Establishment of exclusion zones around fishing areas, boreholes and springs (known impact, appropriation of natural asset) • Construction of material offloading facility (construction jetty)
Construction (Duration of approximately 2 years)	• Clearing of the cement plant site/area - excavation, piling, pouring of concrete foundations and establishment of permanent accommodation, offices and workshops • Building structures in concrete and steel for cement manufacturing equipment • Developing internal cement plant roads and drainage • Establishment of bunds, hauling roads, drainage management areas and mine stope markers ahead of mining commencing • Installation of cement plant equipment • Construction of power plant • Installation of conveyor system • Piling and construction of jetty • Construction of internal access roads and haul roads • Discharge into landfill – solid and liquid waste

Operation Duration of approximately 35-50 years)	• Mining 24hours a day, 7 days a week • Blasting • Truck hauling • Operating conveyor transporting material to/from Jetty • Operational cement plant • Operational power plant operational • Operational jetty and MOF • Maintenance clearing within the plant site boundary (e.g. tree lopping for power lines) • Discharge to landfill – solid waste
De-Commissioning (Duration of approximately 5 year)	• Mine Closure and Rehabilitation

Table 1-2: Summary of Baucau Cement Project Characteristics

Element	Description
Project life	Limestone reserves for over 17years at full production capacity Life of the cement plant is 50+ years
Investment	$400 million USD Largest industrial project undertaken in Timor-Leste to date
Annual production	1.65 million tons per annum (mtpa) of Portland cement clinker (main component of cement; • 0.5 mtpa will be combined with the other required components to make Ordinary Portland Cement (a complete cement mixture) to be sold locally in Timor Leste and Australia (~70 % in Timor-Leste and ~30% to Australia) • 1.15 mtpa will be packaged as Portland cement clinker and exported by ships to Australia

Cement types produced	 Portland cement clinker	 Ordinary Portland cement
List of major project components	Limestone mine (up to 5.76 km²) Cement processing plant (650 m x 400 m) • Including a construction camp and worker residential area (35 containers of 40 feet in length. 1 office unit, one cafeteria unit, 5 accommodation units each with 24 rooms (120 rooms in total). Fully Enclosed Pipe Conveyor Belt (1.5 km long) Marine Jetty (500 m long)	
Area of disturbance	Limestone mine – 185 ha (1.85km²) Cement Processing Plant + Captive Power Plant + Camp – 80 ha- Note all in one compound (0.8km²) Marine Jetty + pipe conveyor - 1.5 ha (0.015km²)	
Power Supply	30 Mega Watt coal power plant 3-5 Mega Watt Solar Power Plant	
Water Supply	Groundwater from water supply bores at the Uaidei River • 0.35 ML/day for construction • 3.15 ML/day for operation	
Number of jobs	3000 jobs during peak of construction 1000 permanent jobs during operations	

1.2 Objectives

The objective of this surface water impact assessment is to identify surface water risks associated with the proposed Project development and to develop surface water management measures to mitigate risk and to minimise potential impacts on the environment.

The impact assessment is to assess the following two areas separately:

- **Plant & Jetty Area** - including the cement plant, marine jetty, conveyor and associated plant infrastructure; and
- **Mine Area** – including the limestone mine, haul/access roads to cement plant and associated mine infrastructure (buildings, facilities, internal roads, waste dumps, etc).

1.3 Scope of Work

The scope of work for this impact assessment includes undertaking the following assessments for both the Mine Area and Plant & Jetty Area separately:

- Identify surface water related risks associated with the proposed developments and sensitive environmental receptors;
- Identify surface water management measures to mitigate risk and potential impacts on the environment. Present design concepts that:
  - Capture and treat runoff from disturbed or potentially contaminated areas on site;
  - Mitigate the risk of flooding from rainfall runoff;
  - Maintain quantity and quality of flow conditions to downstream environments that are similar under pre and post development conditions; and
  - Protect environmentally sensitive areas such as natural springs which are used for public water supply.
- Complete SWMM modelling to assess the potential impacts of the proposed developments on the frequency and magnitude of streamflow events with the recommended surface water management measures in place.

2 Methodology

The following methodology was adopted for this surface water impact assessment:

- Characterise the existing site conditions;
- Identify sensitive receptors in the project area and the surface water risks associated with the Project;
- Develop surface water management measures to mitigate risk;
- Utilise client supplied topographic contour data and infrastructure layouts to delineate catchment areas under pre and post development conditions;
- Estimate daily runoff from project areas under pre and post development conditions using SWMM modelling software; and
- Complete an impact assessment with proposed surface water management measures in place.

The surface water assessment presented in this report has adopted methods consistent with industry best practice in Australia and East Timor.

3 Existing Site Conditions

3.1 Climate

Climatic statistics presented in Figure 3-1 and Figure 3-3 for Baucau were developed using climatic data recorded between April 2010 and March 2014 at the Baucau Meteorological Observatory in East Timor. This data was provided by the Meteorological Department at the Nicolau Lobato International Airport at Dili.

Timor-Leste lies in a tropical region where temperature varies by only 2-3 degrees Celsius (°C) between the warmest months and the coolest months. The average daytime temperature in coastal areas of the Baucau region is around 27°C and around 25°C in the highlands.

Timor-Leste has two distinct seasons, a dry season from June to November and a wet season from December to May. The wet season is characterized by extreme rainfall over short periods created by the West Pacific Monsoon. Torrential rain storms and cyclones commonly occur in the country during the wet season.

3.1.1 Temperature

Average monthly temperatures presented in Figure 3-1 show that maximum temperatures of approximately 31°C occur between November and December, while the lowest average minimum temperature of 17°C occurred in August.

3.1.2 Rainfall

The average annual rainfall recorded between 1st April 2010 and 28th February 2015 at the Baucau Meteorological Observatory was 1384 mm. Approximately ninety percent of the annual rainfall occurred each year between October and May. The average number of rainy days varied from 100 to 140 during this period with an average of 125 days each year. The maximum daily rainfall recorded over this monitoring period was 203.1 mm on the 2nd February 2012. This was a significant rainfall event and was likely to have caused widespread flooding. A plot of the daily rainfall record is provided in Figure 3-2.

The average monthly rainfall data presented in Figure 3-3 shows the majority of rainfall falling during the wet season with over 100mm falling in each month on average, peaking in February at around 300mm. During the dry season (June to November), average monthly rainfall in Baucau is less than 100 mm, with almost no rain recorded during the month of August.

3.2 Topography

3.2.1 Mine Area

The area of the proposed limestone mine site consists of undulating terrain with small hills and a valley. The elevation rises gently from north to south (Figure 3-4). The north-west corner has an elevation of approximately 25 m above mean sea level and the south-east corner has an elevation of about 395 m. The digital terrain model of the topography of the limestone mine area is shown in Figure 3-5.

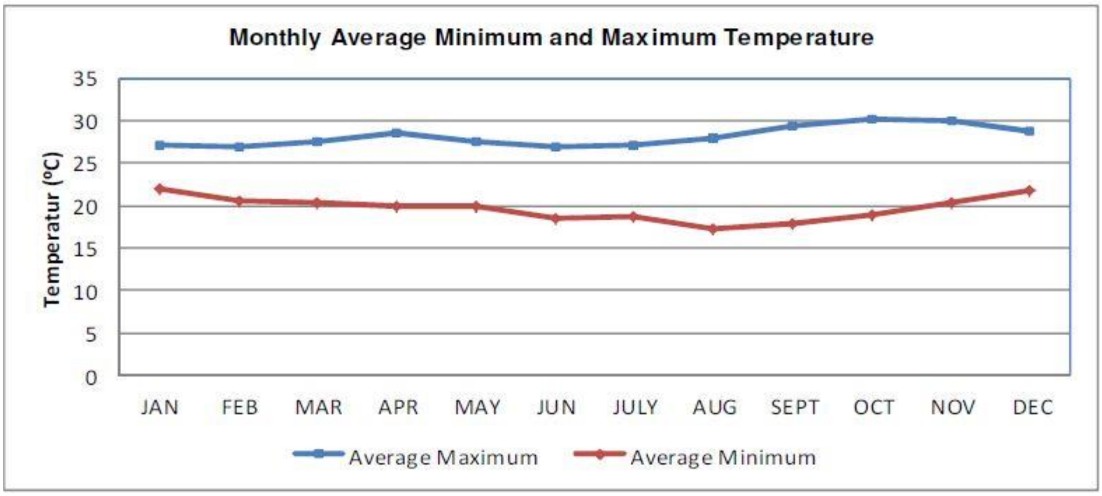

Figure 3-1: Average Monthly Temperatures recorded at Baucau Meteorological Observatory

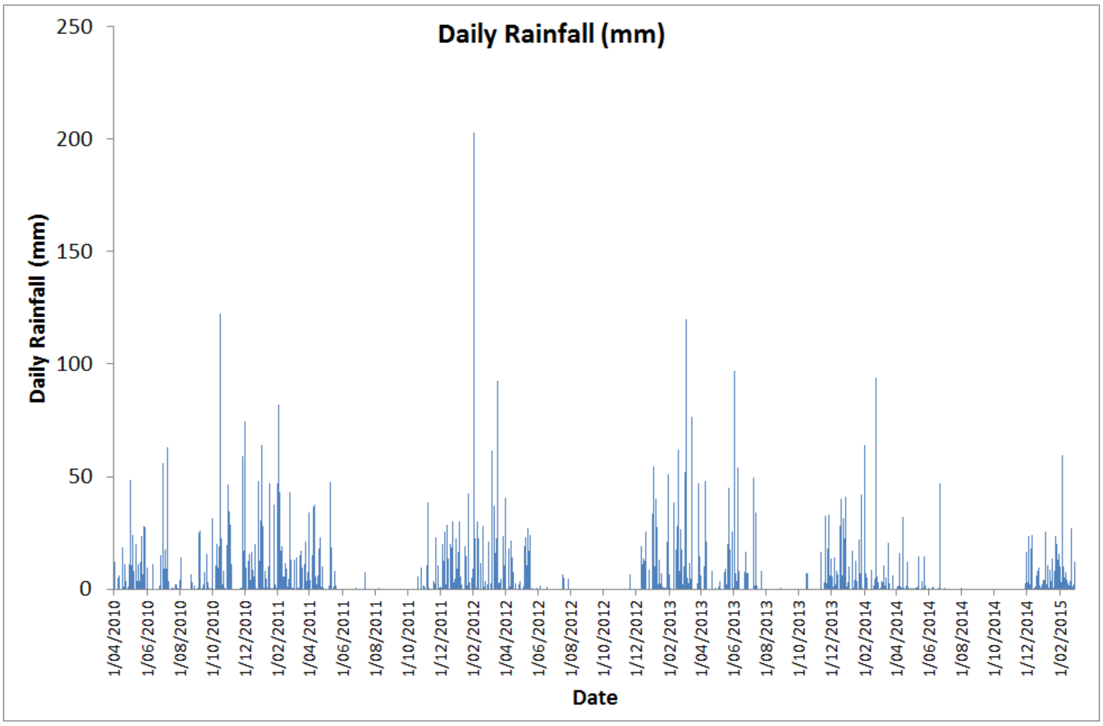

Figure 3-2: Daily rainfall recorded at Baucau Meteorological Observatory between 1st April 2010 and 28th February 2015

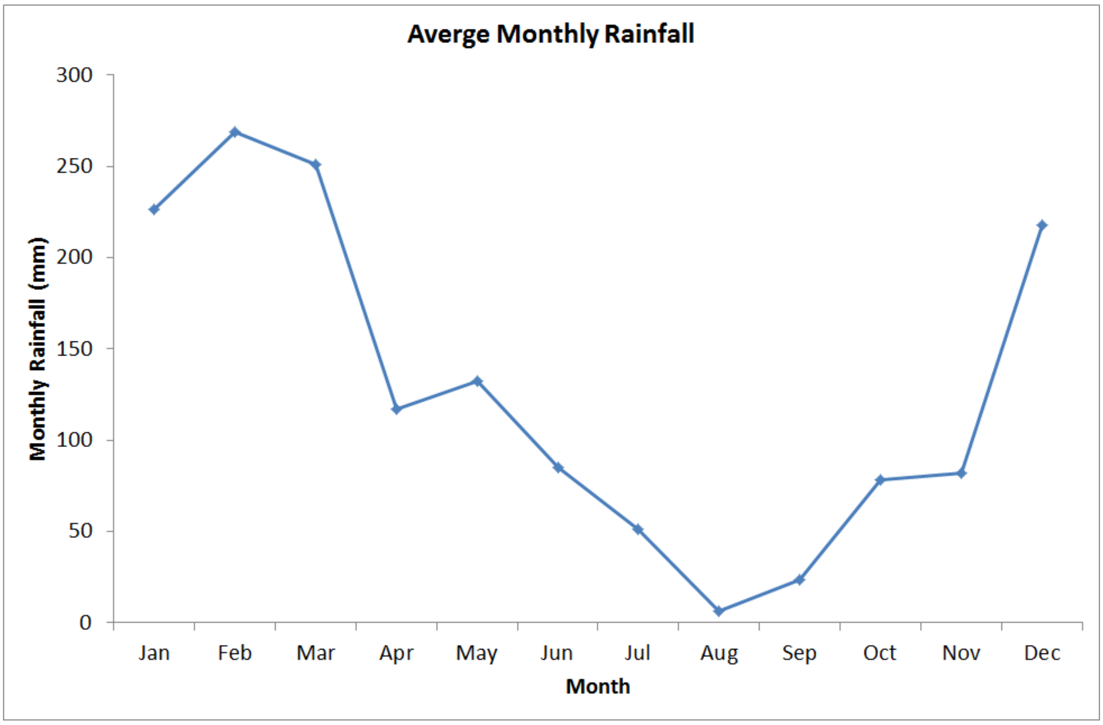

Figure 3-3: Average Monthly Rainfall recorded at Baucau Meteorological Observatory between 1st April 2010 and 28th February 2015

Figure 3-4: Topography of mineral license area looking from north to south

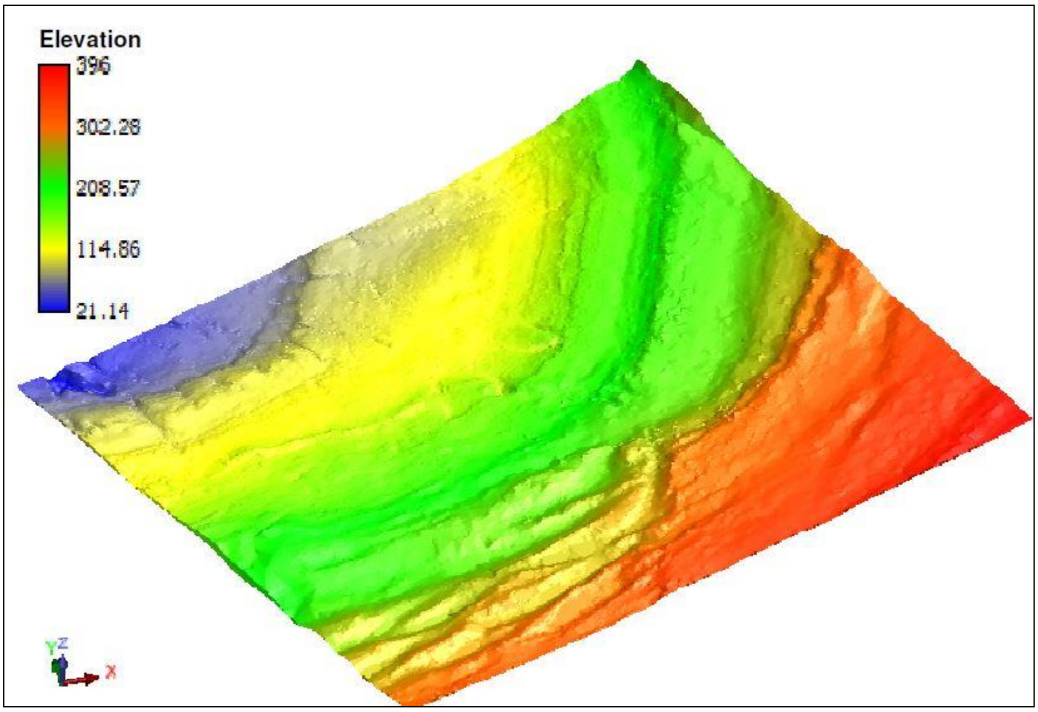

Figure 3-5: Digital terrain model of topography for limestone mine area (m above sea level)

3.2.2 Plant and Jetty Area

The area proposed for the cement plant site is characterized as hilly and slopes up away from the coast (Figure 3-6). The site is 40 m to 50 m above sea level and 0.9 k m to the south east of the proposed jetty.

Figure 3-6: Panoramic view of limestone mine site and plant site

3.3 Surficial Soils

3.3.1 Mine Area

The mine site is located across stepped slopes and plains on limestone outcrops with higher slopes on the southern edge of the site and flatter plains towards the northern boundary. There are minor ravines and gullies, and grassland present. The site is characterized by shallow limestone soils and extensive scattered, small to medium sized limestone rock outcrops (Trainor & Easton 2015).

3.3.2 Plant and Jetty Area

The plant site is located on north-north-east facing slopes and plains relatively close to the beach, road and proposed jetty area. The site is characterized by shallow limestone soils with scattered limestone rock outcrops, minor ridges and gullies sloping towards the beach (Trainor & Easton 2015).

The topsoil in the jetty area generally consists of sandy soils, corals and gravels, with limited indication of very weakly cemented soils. Most soil layers have indication to be calcareous (contain calcium carbonate).

3.4 Regional Hydrology

No permanent rivers exist within the Jetty Area, Plant Site or Limestone Mine areas. Some small ephemeral watercourses flow through the area, mainly during the wet season. These tend to stop flowing in the dry season and are not considered suitable as full time water sources. There are a number of coastal swamps containing fresh water from rain and groundwater discharge, but these also dry up in the dry season.

The closest significant watercourse is the Manulede River located approximately 9 km from the proposed Cement Plant site. The river only flows when there is rainfall but is quite extensive as it drains the western side of the Baucau Plateau (Lindsay 2015). The river also feeds the underground karst aquifer (groundwater) discharge.

Significant catchment areas and drainage lines within the study area were mapped using a Digital Elevation Model (DEM) developed using ASTER data (NASA) and shown in Figure 3-7. The catchment area associated with the mine and plant site has an area of approximately 29.2km^2. Runoff from the higher ground, to the south of the project area, flows northwards, via ephemeral watercourses, toward the ocean.

Karst Baucau limestone is present throughout the majority of the catchment areas reporting to the mine site, which limits rainfall-runoff. Karst features such as including springs, caves, collapsed caves, sink holes, and sharp outcrops are present in the study area (Furness, 2015). The Baucau Limestone aquifer is recharged by rainfall infiltrating on the Baucau Plateau during the wet season. The infiltration rate for the exposed karst features on the plateau was estimated by Furness (2015) to be approximately 40% of the annual rainfall.

Anecdotal evidence (personal communication L. Furness, 2015) suggests there is very little runoff during rainfall events and therefore surface water flows are only expected in the upper catchment areas during extreme rainfall events. This is evident in the air photographs where watercourses are poorly defined. Watercourses become better defined between the mine site and coastline, in proximity to the plant site where limestone sediment/soils and alluvials are present.

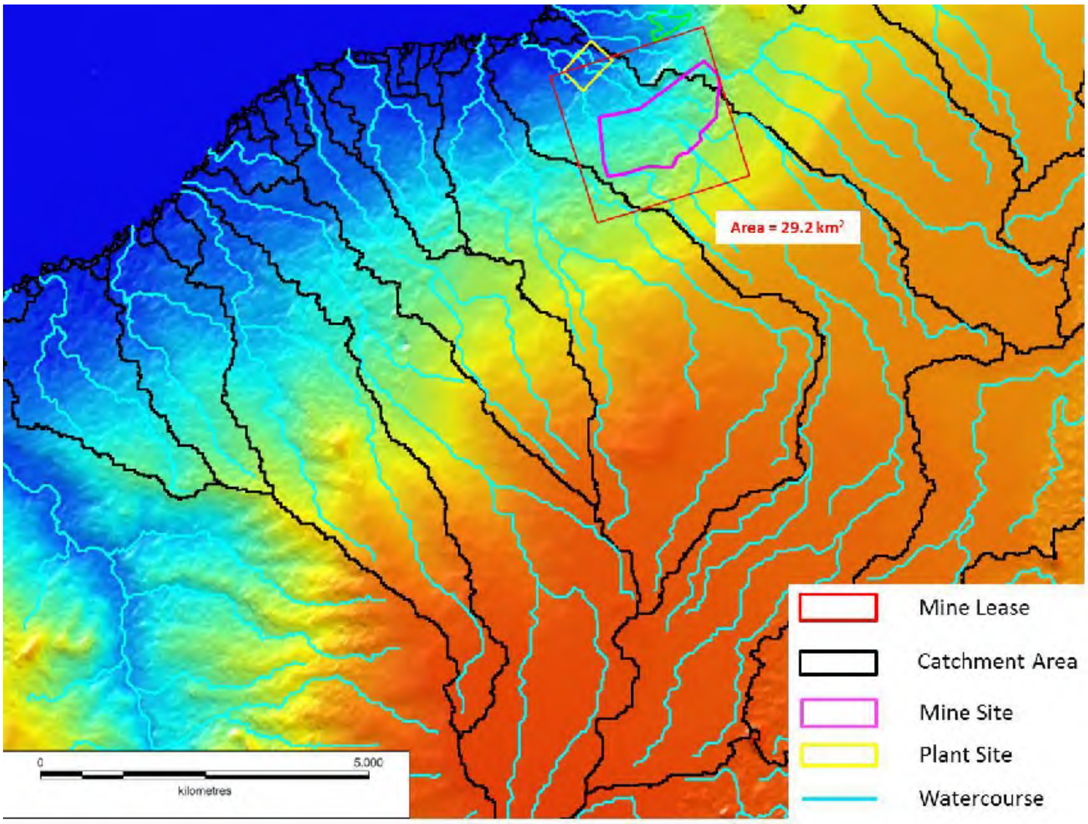

Figure 3-7: Catchment areas delineated using ASTER data (ASTER GDEM is a product of METI and NASA.).

Figure 3-8 shows the known surface springs (triangles) and caves (circles) located on the Baucau Plateau. Springs in the vicinity of the plant and mine areas are shown in Figure 3-9 and include the following:

- Uaimatabai Spring (Plate 3-1);
- Uaisa Spring (Plate 3-2); and
- Uaiono Spring (Plate 3-3).

Uaimatabai Spring emerges from a limestone cave (170 m elevation) along an overhang. The discharge is about 5 L/s and the water is fresh although probably hard (Furness, 2015). Uaisa Spring is the major spring discharge (142 m elevation) located about 400 m downslope of Uaimatabai Spring. It is close to the Caisidu Village School and surrounded by very tall breadfruit and rainforest trees. The discharge is approximately 10 L/s and the water is fresh at 633 µScm. Water is piped and run in open channels to the sub-villages at lower elevation. Furness (2015) recommended that a water reserve is established around these important springs (Figure 3-9).

Uaiono Spring discharges into the sea at the proposed port and jetty area through a fracture in beach rock. Anecdotal evidence from a recent site visit suggests that it is only observed at low tide (L. Furness, 2015).

Figure 3-8: Karst features of the Baucau Plateau. Spring locations are shown as “triangles” and caves shown as “circles”

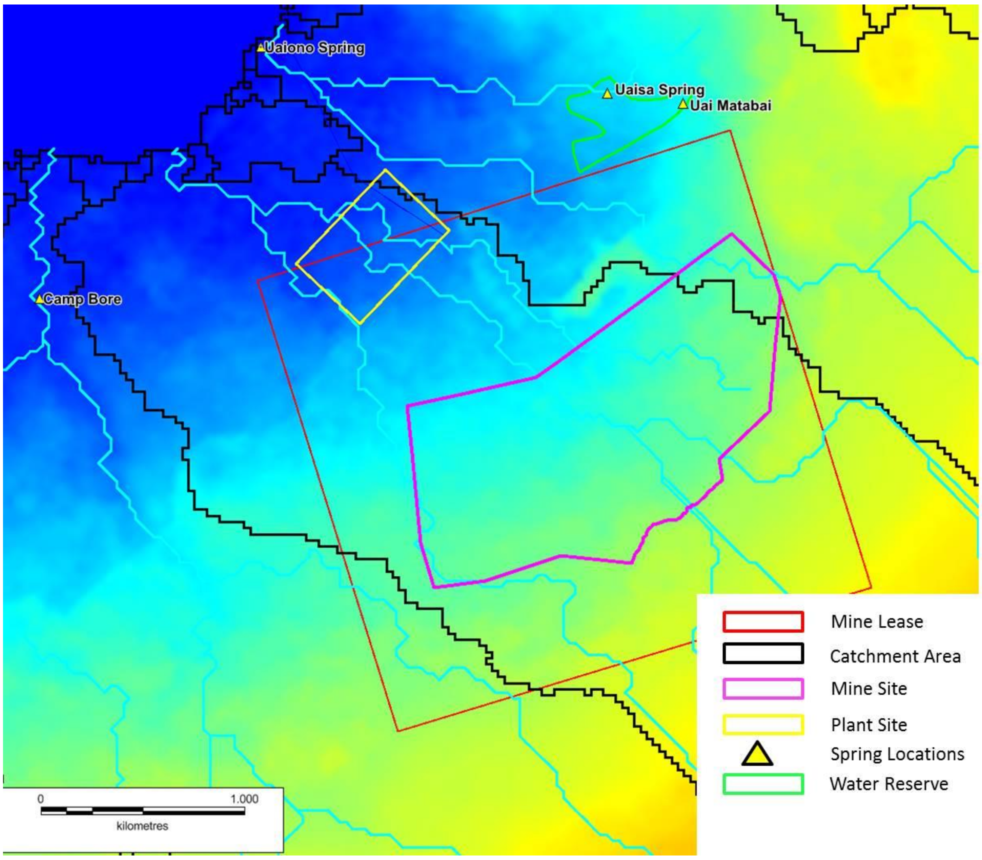

Figure 3-9: Springs in the vicinity of the proposed plant and mine areas.

Plate 3-1: Uaimatabai Spring

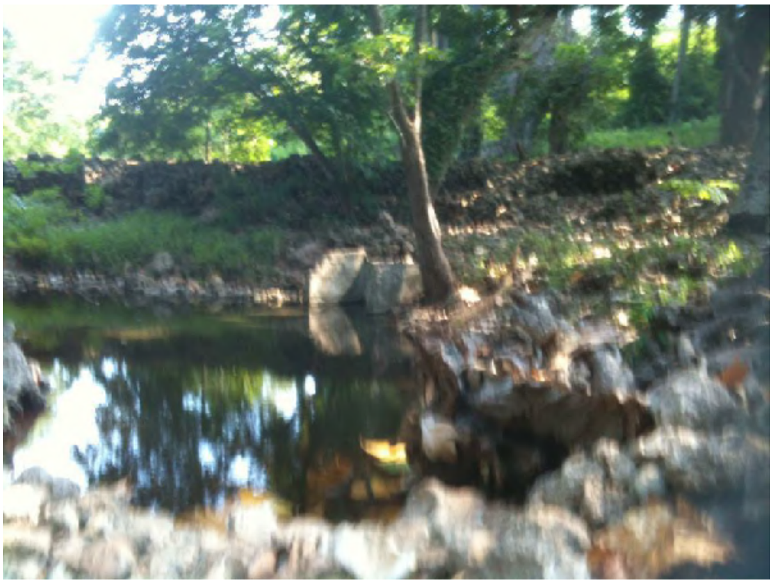

Plate 3-2: Uaisa Spring

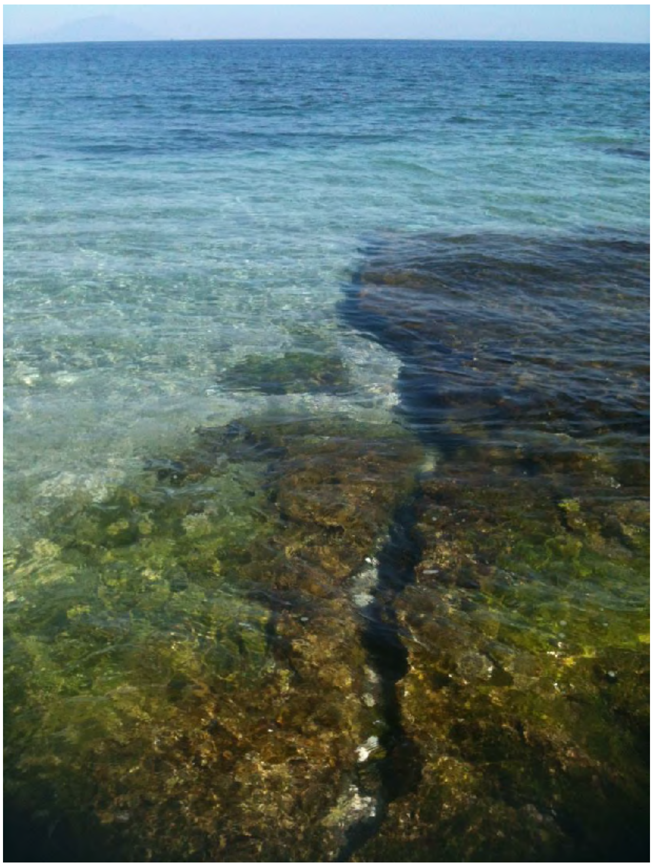

Plate 3-3: Uaiono Spring

4 Environmental Receptors

4.1 Springs

The following surface water springs identified immediately north of the mine and plant areas (Figure 3-9) are surface water receptors potentially at risk from the proposed mine, plant and port developments:

- Uaimatabai Spring (Plate 3-1);
- Uaisa Spring (Plate 3-2); and
- Uaiono Spring (Plate 3-3).

The surface water flows from Uaimatabai and Uaisa Springs occur all year and are used for potable water supply by the Caisidu Village as well as sub-villages at lower elevation. The Uaisa Spring is also surrounded by very tall breadfruit and rainforest trees. The quantity and quality of flows at the springs need to be protected to minimise impact to the associated environmental and social values.

4.2 Terrestrial Vegetation and Flora

Terrestrial flora communities that are dependent on ephemeral surface water flows in streams and drainage lines also are potentially at risk from the proposed developments. The mine, plant and port developments should be designed with surface water management measures in place to minimise adverse impacts on the quantity and quality of surface water flows which pass to existing streams and drainage lines.

Analysis of aerial photography within the study area suggests the ephemeral streams and drainage lines are generally poorly defined in the upper reaches of the catchments, with little or no riparian vegetation apparent. This lack of drainage definition in the landscape is likely to be due to the presence of karstic limestone, with high infiltration capacities, which limits runoff. Further downstream near the coastline and in the vicinity of the proposed mine, plant and port facilities, the drainage lines are well defined with riparian vegetation apparent in the available aerial photography.

Flora communities are concentrated near the springs where surface water flows occur all year. The vegetation includes breadfruit and rainforest trees.

The following summary of terrestrial flora species was taken from the Vegetation and Fauna Survey (Trainor & Easton, 2015).

4.2.1 Plant and Jetty Sites

The Jetty Site is a heavily modified plantation environment with very low biological diversity. The site is not considered representative of a pristine coastal/beach forest and no plant species listed by the International Union for Conservation of Nature (IUCN) were found.

Closed Canopy Tropical Forest is located along streams and drainage lines in the proposed plant site area, with the remaining areas dominated by very open savannah woodland which has been extensively modified for agriculture and grazing in places. *Intsia bijuga* (Borneo Teak), which was present at survey site P002 (Plate 4-1) in a local topographic depression at the Plant Site, is listed as Vulnerable by the International Union for Conservation of Nature (IUCN) Red List.

The Tropical Forest vegetation located along streams and drainage lines in the proposed Jetty and Plant areas is an important environmental receptor which needs to be protected.

Plate 4-1: *Intsia bijuga* (Borneo Teak) at survey site P002 (207981 E, 9064378 S, Z52L).

4.2.2 Mine Site

The mine site is dominated by uniform woodland to open woodland with isolated small patches of Closed Tropical Forest occurring along streams and drainage lines in ravines and gullies.

There is approximately 10% canopy cover in the woodland areas and significant weeds and degradation from grazing. The Closed Tropical Forest has canopy cover in excess of 70% and exhibited the greatest species richness of all sites surveyed.

Santalum album was present at survey site MI03-001 (208405 E, 9063108 S, Z52L) in the Closed Tropical Forest along a drainage line. It also is listed as Vulnerable on the International Union for Conservation of Nature (IUCN) Red List. The Tropical Forest vegetation located along streams and drainage lines at the Mine Site is an important environmental receptor which needs to be protected.

Plate 4-2: *Santalum album* (MI03-001) associated with the Closed Tropical Forest Area at the Mine Site (208405 E, 9063108 S, Z52L).

4.3 Terrestrial Fauna

Terrestrial fauna communities that are dependent on ephemeral surface water flows in streams and drainage lines are surface water receptors potentially at risk from the proposed developments. The mine, plant and port developments should be designed with surface water management measures in place to minimise adverse impacts on the quantity and quality of surface water which flows to existing streams and drainage lines.

The following summary of terrestrial fauna species was taken from the Vegetation and Fauna Survey (Trainor & Easton, 2015).

4.3.1 Plant and Jetty Sites

The fauna survey identified several species of bats at the Jetty Site as well as a few bird species. The site was characterized as having low to moderate fauna habitat quality because of extensive disturbance to natural vegetation.

The Plant Site consists of predominantly of open woodland with a grassy or weedy ground cover. It is generally under high grazing pressure with large flocks of sheep and free range horses. Overall it provides relatively low to moderate fauna habitat quality because it lacks Closed Tropical Forest, has limited vegetation structure, has limited canopy cover and an absence of sharp topographic relief, cliffs, caves, logs and leaf litter.

The only globally near threatened species recorded at the Plant site was the Cinnamon-banded Kingfisher (*Halcyon australasia*) which is generally considered a Closed Tropical Forest specialist found predominately along drainage lines.

The fauna survey that was conducted suggests that the fauna communities associated with the Closed Tropical Forest vegetation are important environmental receptors which need to be protected in the proposed Jetty and Plant areas.

4.3.2 Mine Site

The Mine site has a typical woodland-open country fauna comprising mostly introduced or tramp amphibian and reptile species. Five insectivorous bat species and the introduced Black-spined Toad were recorded, as well as several open woodland and tropical forest bird species.

Five of the six near threatened birds recorded during the surveys were recorded on the Mine and in total 14 globally restricted-range species were recorded. The Cinnamon-banded Kingfisher, Timor Oriole *(Oriolus melanotis*) and Timor Figbird (*Sphecotheres viridis)* are typically considered as forest specialist bird species and are therefore associated with the Tropical Forest vegetation on drainage lines. These species are therefore important environmental receptors which need to be protected in the Mine area.

4.4 Marine Flora and Fauna

Marine flora and fauna species potentially could be adversely impacted by contaminated runoff from the proposed port, plant and mine development areas. The mine, plant and port developments therefore should be designed with surface water management measures in place to minimise adverse impacts on the quality of surface water flows discharging from streams and drainage lines to the ocean.

5 Potential Surface Water Impacts and Mitigation Measures

The potential surface water impacts associated with the proposed plant, jetty and mine developments have been identified with reference to project infrastructure layouts, process flow diagrams as well as the Environmental Guidelines for the Concrete Batching Industry (EPA, 1998) and Western Australian Water in Mining Guideline published by the Department of Water (DoW, 2013).

5.1 Common Impacts and Mitigation Measures

Table 5-1 presents the potential impacts are common to the proposed plant, jetty and mine sites. Mitigation measures are also presented to manage surface water risks and minimise impacts on the environmental receptors identified in Section 4.

Table 5-1: Potential impacts and mitigation measures common to all areas

Potential Impact	Mitigation Measure
Modification and interruption of the existing hydrological regime. This may be caused by: ▪ Blocking of natural drainage lines and creation of ponded areas upstream of development areas with water "shadows" downstream; ▪ Increase or reduction in rainfall-runoff from development areas due to changes in impervious fraction or from changes to surface interception and infiltration characteristics; ▪ Changes to the natural flow frequency and volumes in streams and drainage lines; and ▪ Alteration of recharge rates which sustain the natural springs providing potable water to local communities.	Installation of culvert and/or floodway waterway crossings along access/haul roads to maintain flow paths. Diversions are to be redirected back into the same watercourse downstream where possible to minimize impacts on the hydrological regime. Runoff from disturbed areas is to be managed using drainage systems to minimize impacts on the hydrological regime and recharge to aquifers. Incorporate detention/sedimentation basins into the drainage design if/as required and allow for discharge of treated runoff back to natural watercourses.
Erosion of exposed surfaces by wind, water and construction activities generating increase sediment loads in surface runoff flows discharging to downstream. The potential impacts of increased sediment load in the runoff include sedimentation within vegetated areas, springs, pools, marine environments and other sensitive ecological areas. It also increases turbidity which can reduce the amount of light entering an aquatic	Divert floodwater from undisturbed catchment areas around mine and plant sites to prevent mixing with runoff from disturbed areas, and to protect the infrastructure from flooding during extreme rainfall events. Capture direct rainfall runoff from disturbed areas (cleared areas, stockpiles, waste dumps etc) in drainage systems and direct it to sedimentation ponds to remove suspended sediment prior to discharge to the

Potential Impact	Mitigation Measure
environment which affects the rate of photosynthesis by plants and reduces the visibility of aquatic organisms. In addition, turbidity can clog fish gills, smother aquatic flora and fauna and adversely impact on the general amenity of an area. The potable water supplies used by local communities (springs and streams) also could be adversely affected by sedimentation and increased turbidity.	environment. This will prevent direct discharge of suspended sediment loads into the environment. Sedimentation ponds should be designed to capture sediment particles greater than or equal to 75μm (fine sand/silt) prior to discharging the treated water into the downstream environment.
Mobilisation of hydrocarbons in surface water runoff from site, particularly during rainfall events, which has the potential to contaminate watercourses, springs (water supplies) and marine environments. Potential spillage or discharge of hydrocarbons stored, handled or transported on site is a significant risk to surface water quality during all phases of the project. Transport, storage and handling of hydrocarbons must be carefully managed.	Management plans will be developed to contain contamination at source, to remediate spills, to control dust and erosion and to protect flora and fauna. During both construction and operations, care must be taken to minimise generation of contaminants and to restrict transport to groundwater and surface waterway systems. Hydrocarbons will be managed to avoid leaks and spills. Fuel handling areas will be bunded to capture any spills for remediation and will be located outside of floodplains and karst limestone areas and appropriately elevated to avoid the risk of flood inundation. Bunded areas must be capable of containing the combined volume of runoff from a 20 year ARI 72 hour duration design flood event and 110% of the tank contents in accordance with the DoW Water Quality Protection Guidelines (2000). Stormwater runoff from workshop pavements, fuel unloading and storage areas and from vehicle washdown areas shall be directed to grit and oil interceptors to remove pollutants prior to discharge of the water. Accidental spills outside controlled areas must be appropriately remediated to avoid contamination of groundwater or surface waters.
Generation of Acid Sulfate Soils (ASS) which can lower surface water pH levels and impact on environmental receptors.	It is understood that the risk of Acid Mine Drainage is low as no acid forming material has been encountered (Holtec Consulting, 2015). Therefore there are no apparent potential impacts associated with the formation of AMD.

Potential Impact	Mitigation Measure
	More detailed geochemical characterisation of the materials is needed to confirm AMD potential.

5.2 Plant and Jetty Sites

The site specific surface water risks at the Plant and Jetty areas are presented in Table 5-2 along with the mitigation measures to minimise impacts to the environmental receptors identified in Section 4.

Table 5-2: Potential impacts and mitigation measures specific to the Plant and Jetty area

Potential Impact	Mitigation Measure
The proposed plant site intersects 3 significant ephemeral drainage lines/streams (Figure 3-8 and Figure 3-9). These watercourses pose a potential flood risk to the plant area. There is also a risk that uncontrolled streamflow through the plant site could scour the site, mobilise suspended sediment which could discharge into watercourses downstream and impact on environmental receptors.	The 2 diversion routes presented in Figure 5-1 are recommended for the plant site to: ▪ Direct clean runoff from undisturbed catchment areas around the plant site and to prevent mixing with runoff from disturbed areas and stockpiles; ▪ Protect the plant infrastructure from flooding during extreme rainfall events. It is recommended that the diversions are designed to protect the plant site from flooding during the 100 year ARI event. A concept design for diversion drains and bunds is provided in Figure 5-2. Rock protection is to be included in the diversion design where velocities are high to prevent scour, erosion and sedimentation downstream. Diversions designs should not increase flood risk to local communities. No surface water mitigation measures are required for the conveyor as it is raised and covered so will not impede surface water flows or impact on water quality.
An increased volume of runoff is expected from the plant site area due to: ▪ Clearing and compaction; ▪ Paving of some areas; ▪ Roof areas on site buildings. This increased runoff has the potential to impact on the volume and frequency of flows to	As the plant site area (0.82 km²) is only 2.8% of the total catchment area (29.2 km²) contributing flow to the outlet at the coast, the impact of the additional runoff from the plant site on the hydrological flow regime is considered negligible. This is supported by rainfall runoff calculations in Section 6.

Potential Impact	Mitigation Measure
watercourses.	
Access and haul roads within the mine site have the potential to block surface water flows which could impact on the downstream hydrology and associated environmental receptors.	Installation of culvert and/or floodway waterway crossings along access/haul roads to maintain flows. Rock protection included in the design where velocities are expected to be high to prevent scour, erosion and sedimentation downstream.
Direct rainfall runoff from the plant, stockpiles and other disturbed areas may contain suspended sediment/material which could discharge into watercourses downstream and impact on environmental receptors.	Capture direct rainfall runoff from disturbed areas (plant working areas, cleared areas, stockpiles, etc) using internal drains and perimeter and direct it to sedimentation ponds to remove suspended sediment prior to discharge to the environment. This will prevent direct discharge of suspended sediment loads into the environment.
The jetty is raised so will not impede surface water flows. The transfer of material to/from vessels to the jetty has the potential to result in accumulation of sediment on the jetty, which could discharge to the marine environment during rainfall events.	The conveyor transporting clinker to vessels is covered to prevent deposition of sediment on the jetty. Material handling on the jetty should be performed using methods to prevent accumulation of sediment on the jetty. If there are any areas at risk of accumulating significant volumes of sediment, then surface water drainage on the jetty should be designed to direct runoff to sumps to remove sediment prior to discharge to the environment (only if required).
Potential impact of plant site development on surface water flows and surface water recharge to Uaimatabai and Uaisa Springs.	The proposed diversion routes do not impact on the watercourses flowing into the Uaimatabai and Uaisa Springs which are important sources of potable water supply for local villages. The plant and jetty sites are downstream of these springs so do not discharge to the spring areas and therefore do not pose a risk to the water quality at the springs. Recharge to the springs is from regional rainfall recharge to the karst Baucau Limestone over extensive catchment areas (Furness, 2015). The diversion of minor drainage lines in

Potential Impact	Mitigation Measure
	the plant area is not expected to impact on regional recharge maintaining the spring flows (personal communication Furness, 2015).
Potential discharge of hydrocarbons off site to downstream environmental receptors.	Implementation of the mitigation measures presented in Table 5-1 to minimise impacts.

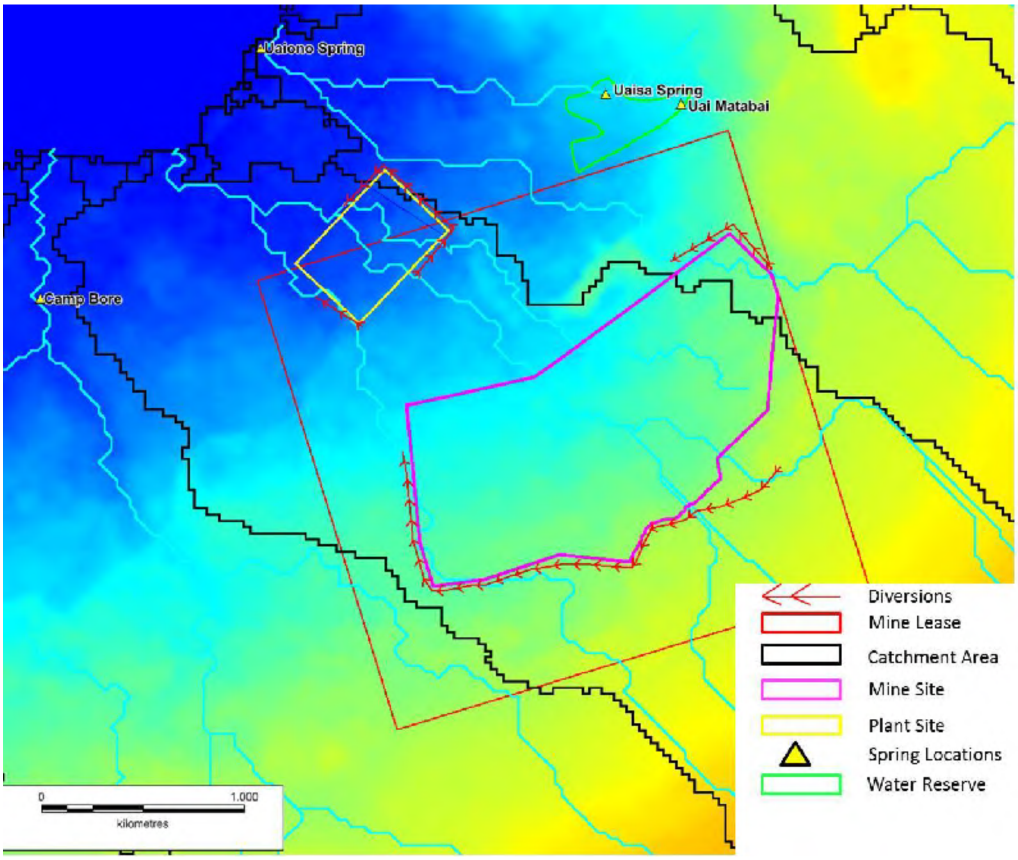

Figure 5-1: Location of conceptual mine pit and plant diversions

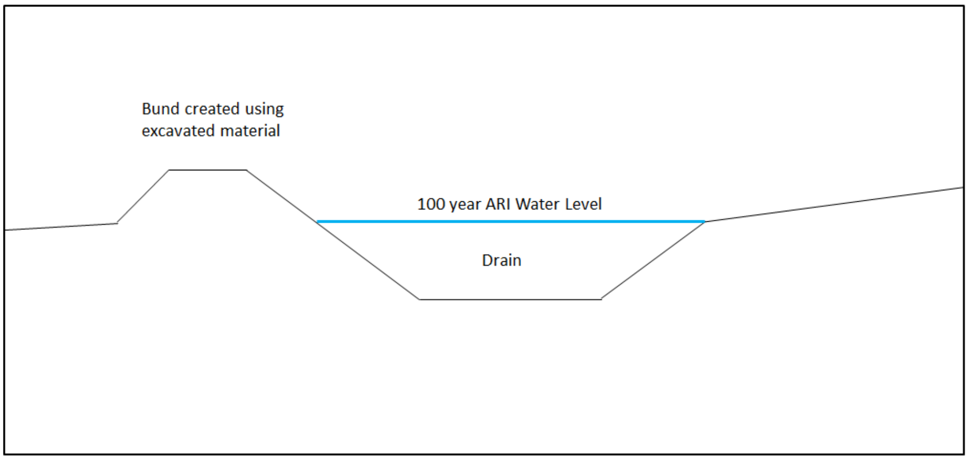

Figure 5-2: Conceptual design for diversions (drain and bund)

5.3 Mine Site

The site specific surface water risks at the Mine site are presented in Table 5-2 along with the mitigation measures to minimise impacts to the environmental receptors identified in Section 4.

Table 5-3: Potential impacts and mitigation measures specific to the Mine area

Potential Impact	Mitigation Measure
The proposed mine pit boundary intersects 4 significant ephemeral drainage lines/streams (Figure 3-8 and Figure 3-9). These watercourses pose a potential flood risk to the mine pit. There is also a risk that uncontrolled streamflow through the mine pit area could scour the site, mobilise suspended sediment which could discharge into watercourses downstream and impact on environmental receptors.	The 2 diversion routes presented in Figure 5-1 are recommended for the mine pit to: ▪ Direct clean runoff from undisturbed catchment areas around the pit and to prevent mixing with runoff from disturbed areas; ▪ Protect the pit from flooding during extreme rainfall events. It is recommended that the diversions are designed to protect the pit from flooding during the 100 year ARI event. A concept design for diversion drains and bunds is provided in Figure 5-2. Rock protection is to be included in the diversion design where velocities are high to prevent scour, erosion and sedimentation downstream. Diversions designs should not increase flood risk to local communities.

Potential Impact	Mitigation Measure
A reduction in the volume of runoff is expected from the pit area as all direct rainfall runoff will be captured in the pit, where it will be either recharged to groundwater or reused on site for mining and dust suppression activities. This reduction in runoff has the potential to impact on the volume and frequency of flows to watercourses downstream.	As the mine pit area (1.8 km^2) is only 6.0% of the total contributing catchment area (29.2 km^2), the impact of the mine pit on the total runoff from the catchment and hydrological flow regime is considered negligible. This is supported by rainfall runoff calculations in Section 6. Runoff during extreme rainfall events may be pumped from sumps in the pits to sedimentation ponds for removal of suspended sediments prior to discharge to the environment to maintain flows in downstream watercourses.
Mine access and haul roads have the potential to block surface water flows which could impact on the downstream hydrology and associated environmental receptors.	Installation of culvert and/or floodway waterway crossings along mine access/haul roads to maintain flows. Rock protection included in the design where velocities are expected to be high to prevent scour, erosion and sedimentation downstream.
Discharge of rainfall runoff containing suspended sediment/material from waste dumps, stockpiles and other disturbed areas to watercourses downstream. This sediment may build up in watercourses and impact on environmental receptors. Potential for watercourses to flood and scour waste dumps which can also lead to sedimentation of watercourses.	Capture direct rainfall runoff from these areas using internal drains and perimeter bunds and direct it to sedimentation ponds to remove suspended sediment prior to discharge to the environment. This will prevent direct discharge of suspended sediment loads into the environment. Divert clean runoff in watercourses and drainage lines around waste dumps using diversions (Figure 5-2).
Potential impact of mining activities on surface water flows and surface water recharge to Uaimatabai and Uaisa Springs.	The mining activities do not impact the catchments providing surface water flows to the Uaimatabai and Uaisa Springs. Recharge to the springs is from regional rainfall recharge to the karst Baucau Limestone over extensive catchment areas (Furness, 2015). The diversion of minor drainage lines and capture of small volumes of rainfall in pits is not expected to impact on regional recharge maintaining the spring flows (personal communication Furness, 2015).

Potential Impact	Mitigation Measure
Potential discharge of hydrocarbons off site to downstream environmental receptors. Previous hydrogeological assessments (Furness, 2015) suggest that the presence of highly transmissive karst features may provide some hydraulic connection between the mine pit and the Uaimatabai and Uaisa Springs. Accidental spillage of hydrocarbons in the pit poses a significant risk to the water quality as this may be rapidly transported in surface water flow and recharge during rainfall events.	Implementation of the mitigation measures presented in Table 5-1 to minimise potential impacts.

6 Catchment Yield Analysis

The hydrology of the study area was modelled using SWMM modelling software to simulate daily runoff under the following scenarios:

- **Pre-Development Scenario:** Representing existing conditions;
- **Operational Scenario:** Based on ultimate mine plan and with all project infrastructure and diversions in place. The location of diversions is shown in Figure 5-1. This assessment will evaluate the impacts of the plant & jetty and the mine site separately as well as a combined impact assessment; and
- **Closure Scenario:** With the site rehabilitated in accordance with the Mine Closure Plan developed by Holtec (2015). The closure scenario assumes that the plant site is rehabilitated and of the total mine pit area (1.82km^2):
  - 1.33 km^2 will be backfilled;
  - 0.38km^2 will be left as a water reservoir (surface water runoff capture area); and
  - 0.11km^2 will comprise rehabilitated benches.

The model calculates rainfall runoff for delineated catchment areas and routes the runoff through the drainage network. The software can account for storage effects, infiltration losses based on soil type and is able to estimate runoff from both pervious and impervious areas.

Without the availability of appropriate calibration data however, the models have been set up using typical values for the principal hydrologic loss parameters and using anecdotal evidence of catchment response to rainfall (personal communication L. Furness, 2015). The results presented are intended to focus on the differential effects on surface water flows expected to be produced by the proposed developments rather than absolute values for flow and volume.

6.1 Model Inputs

6.1.1 Catchment Parameters

Topographic contour data and mine, plant, mine and other infrastructure layouts were used to delineate catchment areas and mainstream lengths for each scenario (Figure 3-7). The effects of the jetty were not included as the construction of the jetty and conveyor is not expected to impact on surface water flows. The impacts of each model scenario were evaluated by assessing the estimated total daily flows at the downstream end of the catchment where it discharges into the ocean.

For the plant site area, an equivalent impervious fraction of 90% was assumed to account for areas that have been cleared and compacted, for roof areas and for areas that are paved. The remaining parts of the catchment also contain significant areas of outcropping limestone, so an impervious fraction of 15% was assumed across the catchment and this runoff routed through the pervious karst limestone areas.

Infiltration losses were applied to all remaining pervious areas using the Green Ampt Method with representative soil parameters adopted as shown in Table 6-2. The soils are predominantly shallow limestone soils, so the equivalent SWMM soil type adopted for simulations was Sandy

Clay Loam. An initial loss (depression storage) of 10mm was applied to pervious areas and 5mm to impervious plant site areas.

The catchment characteristics for each of the scenarios are listed in Table 6-1.

Table 6-1: Catchment characteristics adopted for model scenarios

Sub-Catchment Description	Contributing Catchment Area (km^2)	Mainstream Length (km)	Catchment Slope (%)	Percent Impervious
Scenario: Existing Conditions				
Main catchment	29.2	17.2	4.2%	15%
Scenario: Operations – Mine				
Main catchment	27.4	18.8 *	3.9%	15%
Pit area	1.8	-	-	No runoff as direct rainfall is intercepted by pit
Scenario: Operations – Plant				
Main catchment	28.9	18.3 *	4.0%	15%
Plant site area	0.30	0.5	5.0%	90%
Scenario: Operations –Plant and Mine				
Main catchment	27.1	19.0 *	3.9%	15%
Plant site area	0.30	0.5	5.0%	90%
Pit area	1.8	-	-	No runoff as direct rainfall is intercepted by pit
Scenario: Closure				
Main catchment	28.8	18.8 *	3.9%	15%
Water reservoir	0.4	-	-	No runoff as direct rainfall is intercepted by reservoir

* Slight increase in mainstream length due to diversions.

Table 6-2: Adopted Green-Ampt Infiltration parameters (SWMM Runoff Variables)

Soil Type Equivalent *	Average Capillary Suction (mm)	Saturated Hydraulic Conductivity (mm/hr)	Initial Moisture Deficit
Sandy Clay Loam	218.5	3.0	0.250

* Soil types selected from available list in SWMM

6.1.2 Daily Rainfall Data

Daily rainfall recorded between April 2010 and March 2014 at the Baucau Meteorological Observatory in East Timor (Section 3.1) was used as input into the model. Each daily rainfall total was distributed uniformly over a nominal 6 hour period in each day (ie. Each daily rainfall total was assumed to fall within a 6-hour period).

It is recommended that a pluviometer rainfall gauge is installed on site to collect rainfall at 5 minute intervals to improve the accuracy of rainfall data and runoff estimates.

6.2 Results

SWMM modelling was completed for each of the scenarios presented in Table 6-1. The SWMM model results were used to estimate the runoff coefficients over the 5 year simulation period. The average runoff coefficients presented in Table 6-3 show the average simulated runoff coefficient was approximately 1% for all scenarios. The total number of simulated daily flow events greater than 1 m^3/day is also provided. The runoff coefficients and number of flow events was considered reasonable for comparison of relative runoff for each scenario and consistent with the anecdotal evidence of rainfall response. Modelling predicts that only 10% of the rainfall events generated any streamflow over the 5 year period with the remaining events completely infiltrated to the karst limestone (ignoring daily runoff less than 1m^3).

Additional groundwater, rainfall and streamflow monitoring data are needed at the site to confirm the runoff coefficients, catchment yields and recharge to the aquifer.

Table 6-3: Estimated runoff coefficients over the 5 year modelled period

Scenario	Average Runoff Coefficient (%)	Number of Flow Events *
Existing Conditions	0.8%	66
Operations – Mine	0.8%	66
Operations – Plant	0.9%	70
Operations – Plant and Mine	0.9%	70
Closure	0.8%	66

* The total number of rainfall days over the simulation period was 650

The results of SWMM modelling for the scenarios listed in Table 6-1 were used to generate total daily flow frequency plots in Figure 6-1, to allow direct comparison of flow statistics. The plots present the exceedance probabilities for total daily runoff volumes (m^3) at the SWMM catchment outlet for each scenario.

The results show the proposed mine and plant developments have little effect on the frequency and magnitude of streamflow events for all scenarios. This is due to the impacted areas at the mine and plant sites (1.8km^2 and 0.3km^2 respectively) comprising only a small proportion of the total catchment area (29.2km^2).

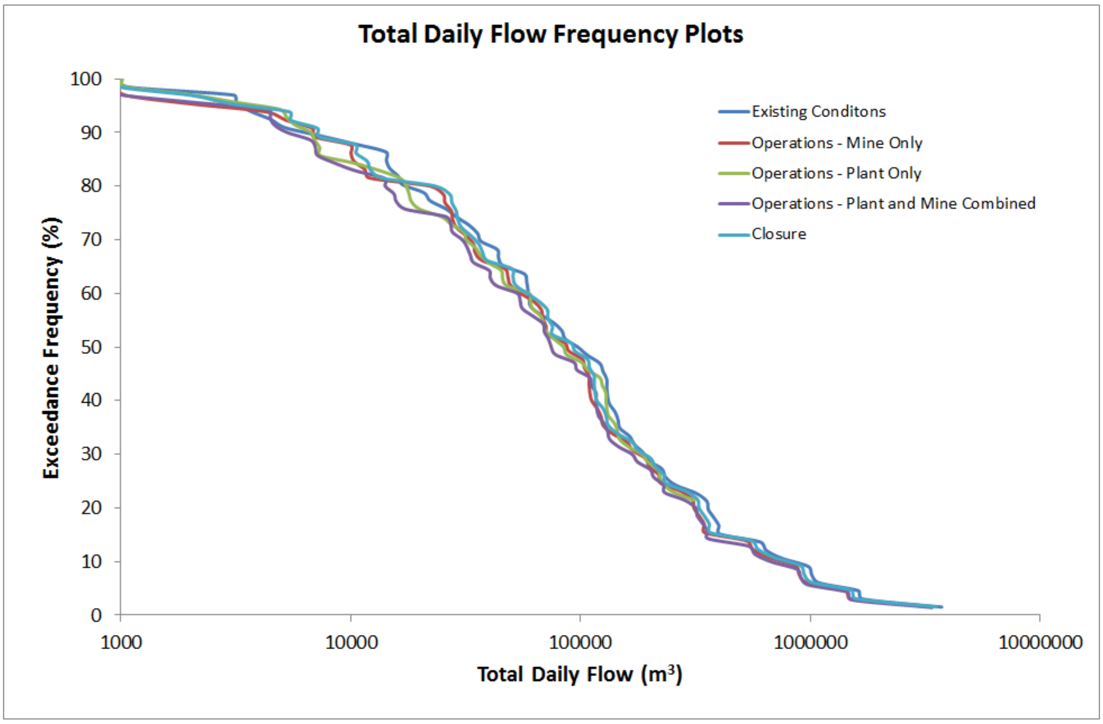

Figure 6-1: Total Daily Flow Frequency Plots: SWMM modelling (April 2010 - March 2014)

7 Conclusions and Recommendations

The results of this surface water assessment suggest the proposed developments associated with the Baucau Cement Project are not expected to have a significant impact on the quantity and quality of streamflow or on the associated environmental receptors in the study area subject to the recommended surface water management measures being put in place.

Areas of social and ecological value that are dependent on runoff, such as the springs used for public water supply, Closed Tropical Forest vegetation identified along watercourses and drainage lines and the associated fauna species will be protected by implementing the surface water management measures outlined in this report. These measures are intended to reduce the risk of changes to the flow regimes and water quality in the local watercourses as a result of the proposed development.

SWMM hydrological modelling of the proposed development area was conducted using 5 years of daily rainfall data. The model was used to generate total daily flow frequency plots for existing, operational and closure scenarios. The results show the proposed mine and plant developments have negligible effect on the frequency and magnitude of streamflow events for all scenarios. This is due to the mitigating effects of the runoff management measures proposed and the relatively small proportion of the total catchment area that is impacted by the proposed development.

The proposed diversion routes around mine and plant infrastructure do not impact on the watercourses flowing into the Uaimatabai and Uaisa Springs which are important sources of potable water supply for local villages. Surface water quality management measures are also presented in this report to minimise the risk of potential contamination of spring water from surface water flows off plant and mine sites.

Although the presence of highly permeable karst limestone limits the volume of rainfall-runoff generated in the catchments areas, there is still some risk of flash flooding during extreme rainfall events. Therefore diversion drains and bunds are proposed in this report to divert floodwater around mine and plant areas. Further hydrological investigations are needed to design diversions, internal drainage systems and culvert-floodway crossings in the mine and plant areas.

The jetty and conveyors are raised so will not impede surface water flows. The conveyors are covered to prevent runoff from cement clinker while being transported to the jetty to minimise impacts on surface water quality.

Monitoring of surface water flows and water quality in watercourses and drainage lines is recommended to establish baseline conditions and for compliance monitoring. It is recommended that a pluviometer rainfall gauge is installed in the catchment as well as water level loggers in watercourses to collect rainfall and streamflow data at sub-daily increments to improve the accuracy of rainfall data and runoff estimates. This data can also be compared with water level logger data in groundwater bores and at springs to improve the understanding of surface-groundwater recharge to the springs.

8 References

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Appendix 4 Preliminary Groundwater Study

WorleyParsons
Consulting

TL Cement

TL CEMENT, LDA

Baucau Cement Project

Preliminary Groundwater Study

301012-02135-EN-REP-0004

7 January 2016

Level 7, QV1 Building,
250 St. Georges Terrace
Perth WA 6000
Australia
Telephone: +61 8 9278 8111
Facsimile: +61 8 9278 8110
www.worleyparsons.com
ABN 61 001 279 812

EcoNomics™

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BAUCAU CEMENT PROJECT
PRELIMINARY GROUNDWATER STUDY

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PROJECT 301012-02135 - BAUCAU CEMENT PROJECT

REV	DESCRIPTION	ORIG	REVIEW	WORLEY-PARSONS APPROVAL	DATE	CUSTOMER APPROVAL	DATE
0	Issued for Use	L Furness	L Siraz	D Hunter	7-Jan-16		

CONTENTS

Appendices

1. INTRODUCTION

The following report is an assessment of the impact of the proposed Cement Plant and Mine at Baucau, Timor-Leste on the groundwater resources of the Baucau region.

1.1 SCOPE OF WORK

The following scope of work was used as a basis for the study:

1.1.1 Desktop Review

A desktop review of existing hydrogeological and geological reports and data, including information obtained through consultation with the BESIK Rural Water Program manager. This shall include available drilling and borehole logs, pump testing and water quality data (and other data such as the recent airborne geophysics survey in the Baucau region).

1.1.2 In country meetings (data gathering)

Attend meetings with representatives from BESIK Rural Water Program (ie Craig McVeigh) the following people to identify and agree on the number and location of water supply bores that will be assumed as the basis for the ESIA (including construction and operational supplies at plant and mine sites):

Attend meetings with representatives from H2O drilling company to obtain knowledge of any historical/current groundwater drilling activities within the project study area and/or the Baucau region. Other stakeholders may be identified and consulted if applicable.

The results of the desktop hydrogeological assessment and meetings with drillers, client and BESIK Rural Water Program manager will be used to inform the development of a conceptual hydrogeological model for the study area.

A summary of all the collected groundwater information from this field investigation is contained in Appendix 3 - .

1.1.3 Site visit

A site reconnaissance / walkover to understand location(s) of proposed infrastructure, potential groundwater sources and to generally get an appreciation of the land formation and probable geo hydrology of the site;

If available, collection of groundwater quality samples.

1.1.4 Impact Assessment

A qualitative assessment of the potential impacts associated with abstraction of groundwater from bores to meet the project water demands will be undertaken. The impact assessment will be based on estimates of drawdown using empirical equations and development of a conceptual hydrogeological model.

The Hydrogeological Impact Assessment report will contain the applied methodology, results of the qualitative impact assessment (including characterization of site hydrogeology) and will also include a groundwater management plan developed for the Project. The report will also have site photos and any applicable maps and figures.

1.2 PROPOSED DEVELOPMENT

According to the Timor-Leste Cement Plant Overview presentation TL CemA a subsidiary of BGC Australia proposed to produce 1.5 million Tons/Year (MTPY) comprising 1.0 MTPY of Clinker bulk and 1.5MTPY Cement for Timor-Leste domestic supply at Baucau. The location of the Plant and Mine areas is shown in Figure 1.

Figure 1 Location of Cement Plant and Mine Facilities

Stage 1 of the site development comprises a new port, industrial complex, cement plant and Mine 1 areas.

The make-up water demand for the operation will be:

Table 1 Daily Consumption of Water

Component	Water Consumption Megalitres/day (Ml/d)
Cement Plant	1.4
Drinking and Sanitation	0.35
Mines and Greenbelt	0.1
Waste Heat Recovery	0.3
Captive Power Plant	1.0
TOTAL	3.15

The total daily make-up requirement is equivalent to 1.15 Gl/yr (Gigalitres per year) or 35 l/s (litres/second) continuous. The source of water has not been defined but could come from a combination of the following possible types:

Table 2 Potential Water Sources

Source	Features
Coastal Alluvium	Yields of 10-30 l/s and mostly salty, fresh in larger catchments
Karst Springs	Fresh water yield of 10 l/s used for irrigation and village water supply
Karst Limestone Aquifer	Large yields of (10-30 l/s) but requires investigation to locate well sites and to define impacts on springs.

Some small rivers flow through the area, mainly during the wet season and tend to stop flowing in the dry season and are not considered suitable as full time water sources. There are a number of coastal swamps containing fresh water from rain and groundwater discharge, but these dry up in the dry season.

1.3 GEOLOGY

The proposed cement plant, facilities and mine areas lie within the Baucau Limestone and some coastal alluvium, underlain by mostly Viqueque Formation and Bobonaro Clay. According to Audley- Charles (1968) the Baucau Limestone is a series of terraced reef limestones that crop out about the town of Baucau. The lithology is a hard, vuggy, cavernous, white coral-reef limestone that weathers to a pale grey colour. The top of the plateau is characterized by karst topography and dark reddish soil. Audley-Charles (1968) divided the formation into four distinct lithologies;

- Coral-reef limestones, insitu growths of coral and calcareous algae.
- Calcirudities, massive poorly bedded conglomerates, composed of reef debris cemented by micrite and sparry calcite.
- Calcarenites, interbeded with the insitu reefs and calcirudites comprised of sand grains of the fragments of corals.
- Submature greywache-pebbly sandstone. Poorly sorted gravels, sands and silts.

The thickness of the Baucau limestone has been identified from geophysics as reaching a maximum of about 80 metres on the plateau. Core drilling by Timor Cement on the flanks of the plateau indicate limestone thickness up to 100 metres. The highest elevation on the Baucau Plateau is about 730 metres, dropping down to about 330 metres at Baucau and then plunging down the escarpment to the sea.

The Baucau Limestone generally unconformably overlies the Viqueque Formtion (marine clay forming an impermeable basement) and is considered to have a maximum age of the Pleistocene (2,588,000 to 11,700 years ago). The limestone has terraces (raised beaches) that decrease in elevation to the present shore-line and therefore ranges from the lower Pleistocene to the Holocene (11,700 years to present).

Underlying the Baucau Limestone are the folded sediments of the Pliocene Viqueque Formation (5.33 million to 2.58 million years ago) comprising mainly white clay. There is evidence now from geophysics that volcanics may occur north of the Baucau Airport, and these may be blocks within the Bobonaro Clay.

The coastal alluvium is up to 60 metres thick and comprises of river alluvium from the major rivers in the area, interbeded with marine deposits from eroded coral and shells, and marine clay.

1.4 HYDROGEOLOGY

1.4.1 Baucau Limestone

The Baucau Limestone karst aquifer has been studied from 2004 to the present to identify the karst features that are likely to supply water to Baucau, New Baucau, the airport, Triloca and the Timor- Leste Cement Plant. It has been observed that the limestone has karst features of springs, caves, collapsed caves, sink holes, and sharp outcrop. A hydrogeological map of Timor-Leste was developed by Geoscience Australia (2010) from the geology map and ground-truthing and is shown in Figure 2. The Baucau Limestone is identified in the study area as the green karst limestone (fissured aquifer (karst) high yield).

Geoscience Australia carried out a review of the groundwater in Timor-Leste and the potential impact of climate change on groundwater resources.

Coastal alluvium is indicated in Figure 2 in dark blue and is located to the west of the proposed Baucau cement mine. In the west the karst is in contact with the coastal alluvium at low elevations and probably recharges the alluvium with discharge from concealed springs. However, on the plateau area the karst aquifer discharges through springs around the edge of its outcrop. This water may re-enter permeable alluvium downslope.

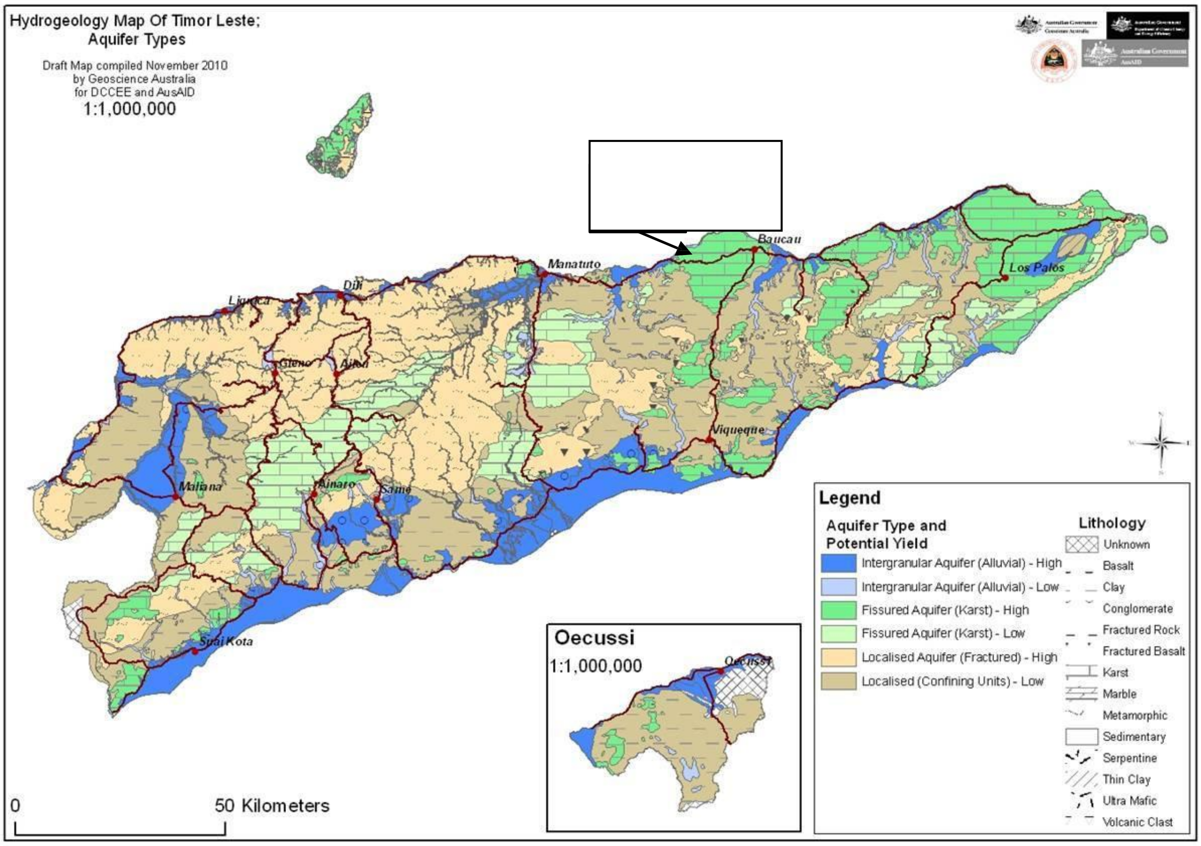

Figure 2 Hydrogeological Map of Timor-Leste (Geoscience Australia, 2010)

1.4.2 Karst Features of the Plateau

The main karst features of the Baucau Plateau includes springs (triangles) and caves (circles) shown on the following Figure 3.

Figure 3 Karst Features of the Baucau Plateau (Furness, 2011, unpublished)

The two largest springs are Uaisarake and Uaililia (Figure 4 & Figure 5) on the eastern side of the plateau and produce 200 l/s and 50 l/s, respectively.

Figure 4 Uaisarake Spring in Baucau

Figure 5 Uaililia Spring

1.5 Recharge, Flow and Discharge

The aquifer is recharged by infiltrating rainfall on the plateau during the wet season. The infiltration rate is very high (c.f. Jocson et al 2014) due to the exposed karst features and probably about 40% of the annual rainfall that varies from about 1,200 mm in Bacau (1956 – 1992) to 1,764 mm on the plateau (Venilale 1952 – 1974). Recharge has been observed by monitoring cumulative rainfall and cave river levels at Uaileaveri Cave. Recharge only takes an hour or two in a storm to infiltrate to the cave stream (about 6 metres (m) below ground level (mbgl)).

Discharge at the main spring in Baucau has been monitored over several years and has been observed that there is a delay of about 9 months between the wet season rainfall and peak flow of the spring. This observation supports the theory that the karst aquifer is bimodal in storage and transmission of water. Fast recharge and flow occurs through fractures and caves whereas very slow flow occurs in the low porosity of the limestone rock mass into the caves.

The flow of the Baucau plateau has been conceptualised based on observations of the elevations of the ground surface and the elevation of water in caves and springs. The general flow pattern of groundwater in the karst is from the high in the south-west to the low in the north-east at Baucau, but also there is lateral movement to the springs in the east and west of the plateau.

A dye tracing experiment was designed and performed (Furness 2011) to test which cave streams were connected to which spring discharges. Four different coloured fluorescent dyes were introduced on the same day to the Uaileaveri, Uaileamata, Huhadili and Uaimatahun caves in the central to upper plateau (Figure 6 & Figure 7). Monitoring for minute traces of dye was carried out on a weekly basis using activated carbon granules that adsorb dye in approximately 12 springs over a 3 month period.

Figure 6 Mixing Dye Powder at Uaimatahun Cave

Figure 7 Introducing Dye in Uaileaveri Cave

The results showed that Eocene dye (yellow) was traced from Uaimatahun cave to Uainoi spring with a travel time less than a week (4 km). Fluoroscene dye (green) in Uaileaveri cave passed through Uaileamata cave in less than a week (1 km) and travelled to Ualilea together with Rhodamine dye (pink) from that cave to Uaililea spring with peak concentration at 2 weeks (7 km). The Sulfrhodamine dye (red) mixed with cave water in the Huhadili cave did not show up in any of the monitored springs. None of the dyes arrived in the Baucau town spring over a 6 month period.

The dye tracing experiment was followed up with time domain EM surveying at Uaileamata Cave and Uaileaveri Cave by CSIRO. The results (Figure 8) show 3 distinct layers of dry limestone (dark blue) at the surface, then wet limestone (light blue) underlain by Clay (orange to red). The thickness of saturation is variable, but is thought to be mainly a thin layer at the base of the limestone.

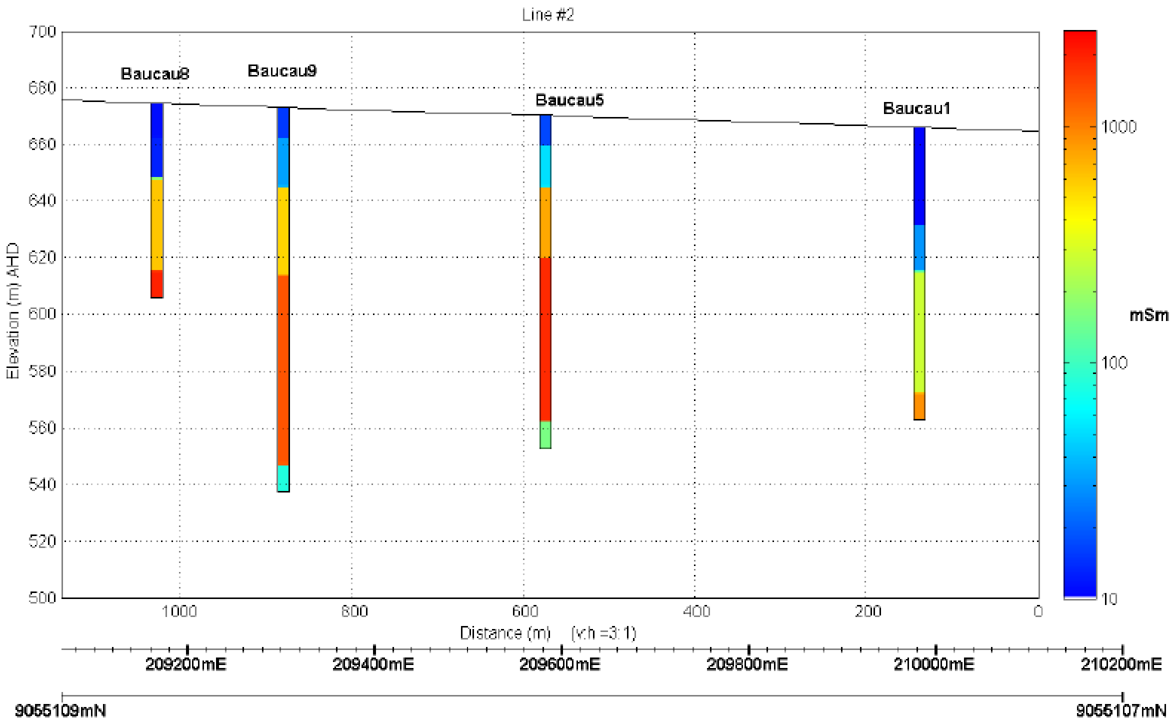

Figure 8 TEM survey results at Uaileaveri (Baucau 8) and Uaileamata (Baucau 1) Caves (CSIRO, 2012)

1.6 Airborne Geophysics

Based on the results of the dye tracing experiment (Furness 2011) and the TEM study (CSIRO 2012) at the caves, it was decided that an airborne geophysical survey of the Baucau Plateau might reveal the features of the karst aquifer and the flow lines of the main fractures and caves. The airborne geophysical study (Furness 2011, Fugro 2012) was planned due to the failure of a number of new bores to locate any water in the limestone around Baucau.

The survey plan included flight lines at 200 metre intervals along the main axis of the Baucau Plateau and extending to the edges of the plateau. The frequency domain electromagnetic method was chosen based on previous experience with the method. The approximate area surveyed by helicopter using the Fugro resolve equipment is shown in Figure 9.

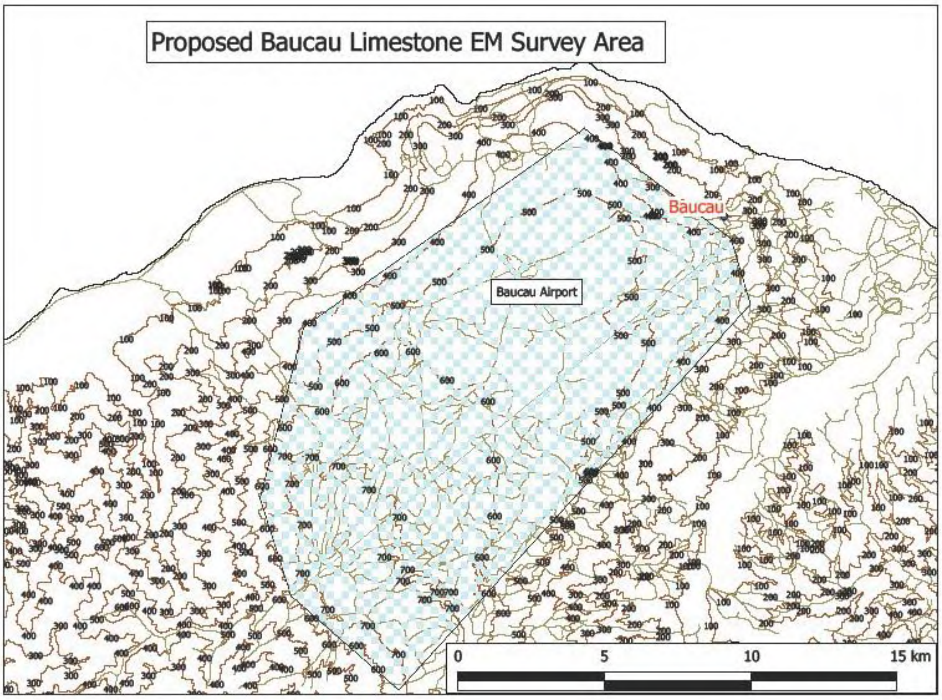

Figure 9 EM Survey Area

The survey lines were flown with the aircraft (Figure 10) at 60 metres above the surface and the survey instrument at 30 metres above the ground. The instrument carried coils that transmit at 6 different frequencies, and a magnetometer, while the aircraft contained a precision altimeter, navigation and recording equipment.

Figure 10 Aircraft and Instrument Pod

1.7 Geophysical Results

The data sampling rate of the survey was about every 4 metres along the flight paths with cross lines every 2 km to check on data integrity. Output from the survey include a precision digital elevation map, vertical and total magnetic fields, 6 frequencies of EM measuring resistivity at successively deeper intervals and a flight location video.

The EM data were inverted to produce a two layer model showing the isopachs of the Baucau Limestone and the elevation of the underlying Viqueque Formation. The results are presented below as a series of maps and cross sections.

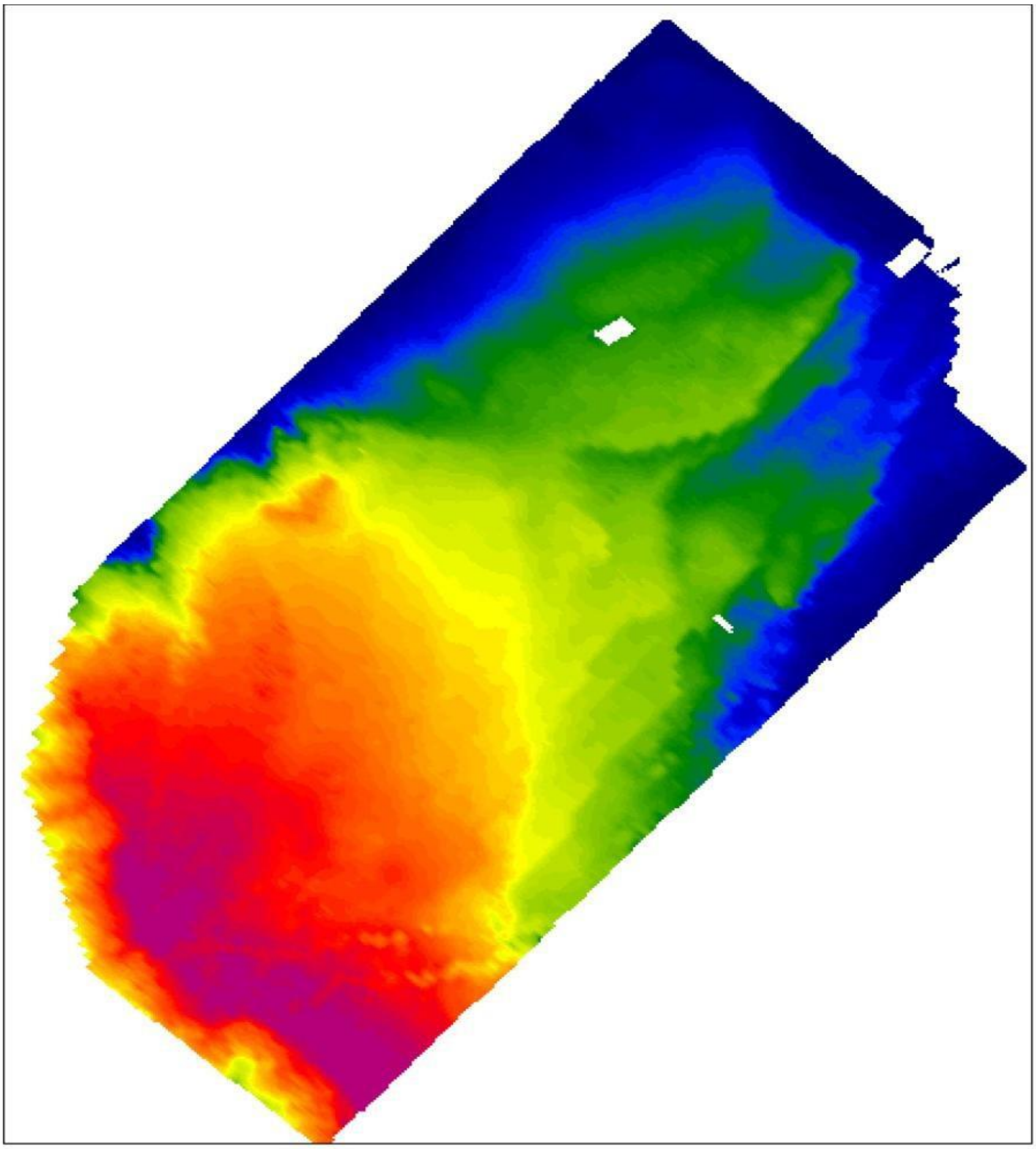

Figure 11 Laser Elevation Map (pink = 730m dark blue = 330m) (Fugro, 2012)

Figure 11 shows the topographic shape of the Baucau Plateau as a series of terraces from 330 m to 730 m elevation above sea level. In the south of the figure there are two collapsed caves (now canyons) in an east-west orientation.

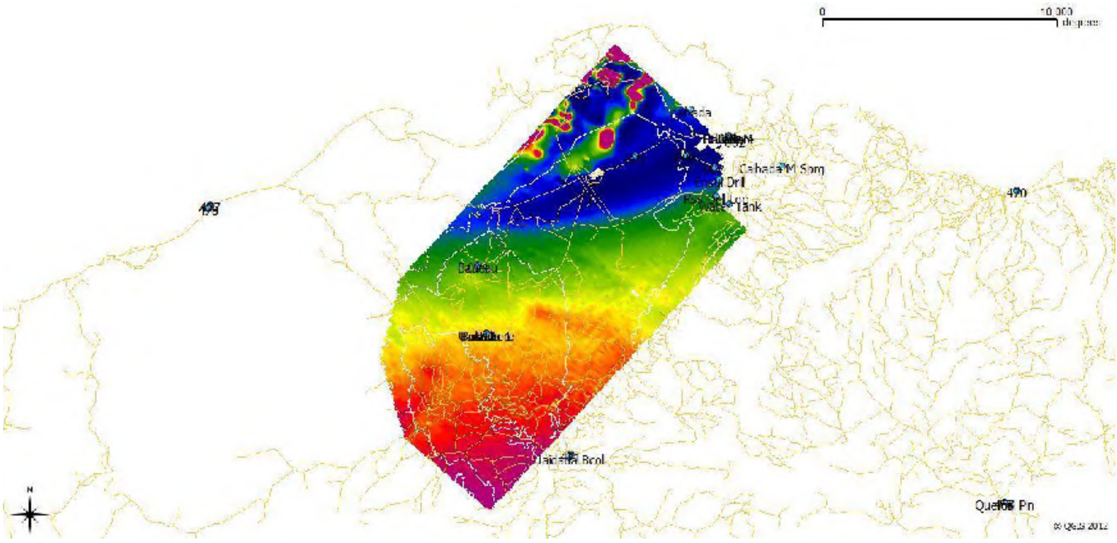

Figure 12 Magnetic Field indicating possible volcanic basement in north (Fugro, 2012)

The magnetic field (Figure 12) show zones of high magnetic contrast in the north that are interpreted to be a volcanic basement.

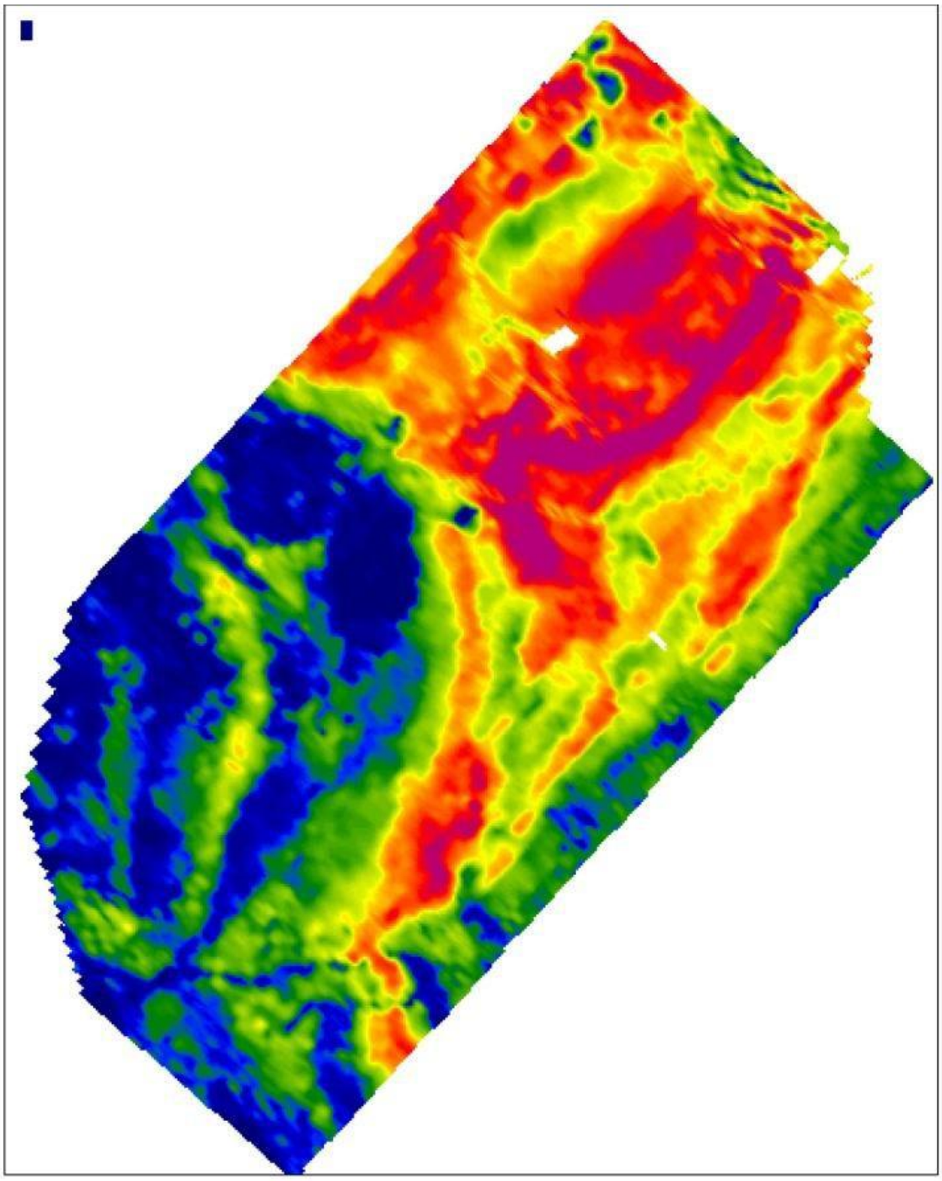

Figure 13 Shallow Apparent Resistivity (140 khz) – (Fugro, 2012)

Legend : blue = low resistivity, purple = high resistivity

Figure 13 shows the apparent resistivity from the 140 khz coil indicating very low resistivity (blue) in south-west in the clay soils and high apparent resistivity (purple) in dry limestone outcrops in the north-east.

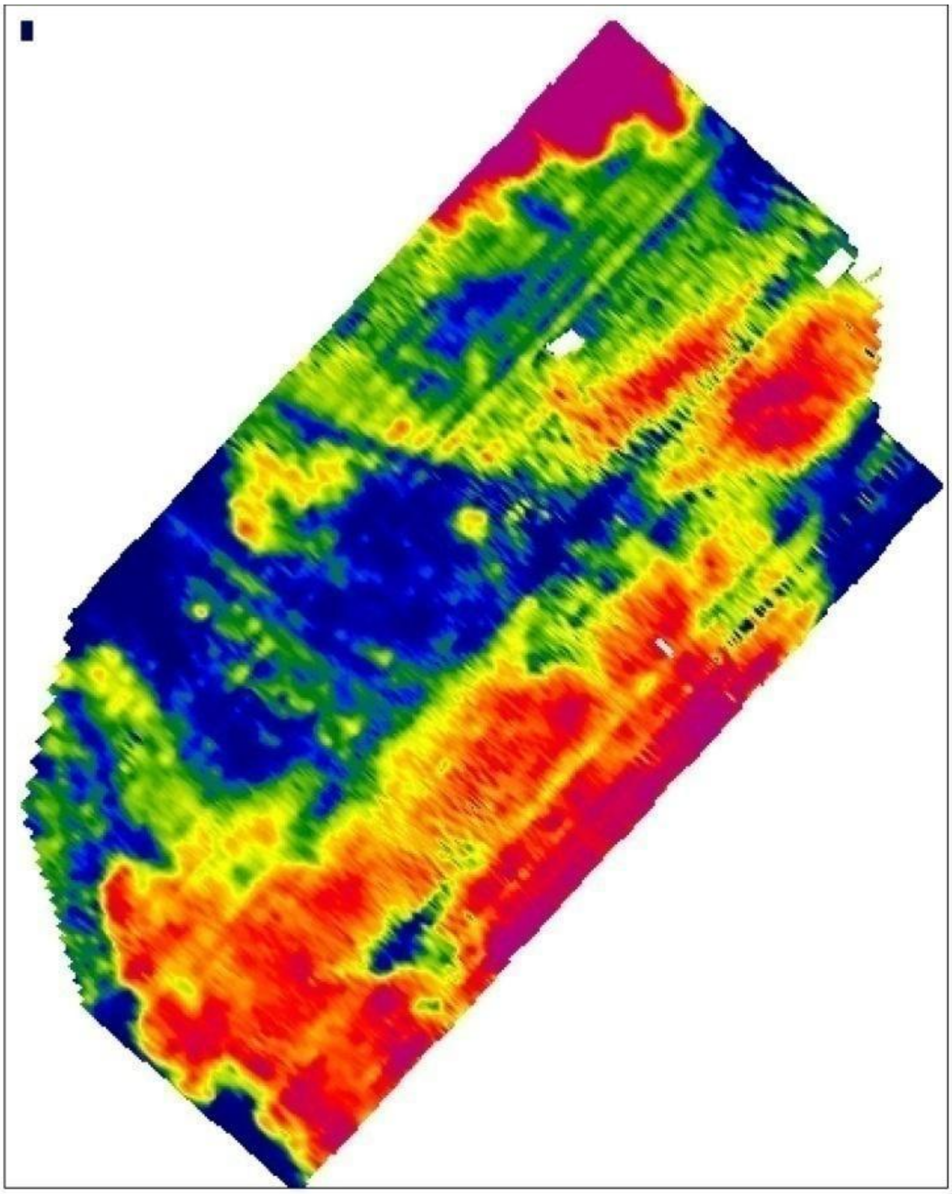

Figure 14 Deep Apparent Resistivity (400 hz) (Fugro, 2012)

Figure 14shows the deepest apparent resistivity from the 400 hz coil mostly in the Viqueque Formation below the Baucau Limestone.

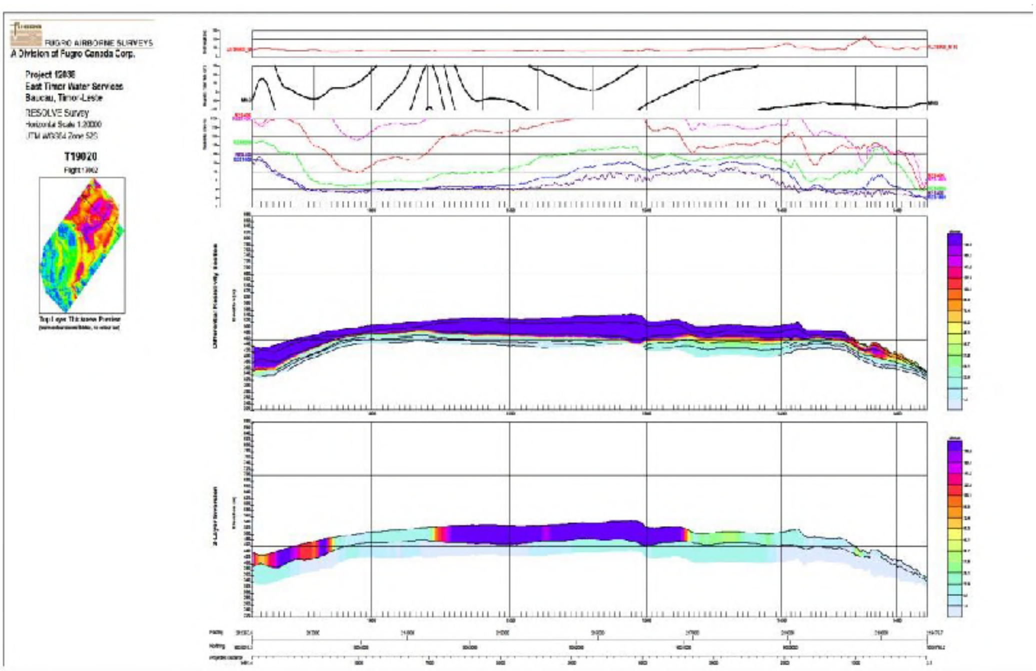

Figure 15 Flight Line 19020 Inversion

Figure 15 shows a cross section of the Flight Line 19270 which was flown south-east to north-west. The upper panel shows the height of the instrument pod with a kick in elevation as the survey crossed high tension electric wires. The second panel is the magnetic field, the next panel is the six coil responses (apparent resistivity). The middle panel shows the apparent resistivity of the Baucau Limestone (purple) clearly draped over the Viqueque Formation. The lowest panel shows the inversion model of the Bacau Limestone indicating highest resistivity in purple. Note the dips in the lower surface of limestone suggesting palaeo drainage lines.

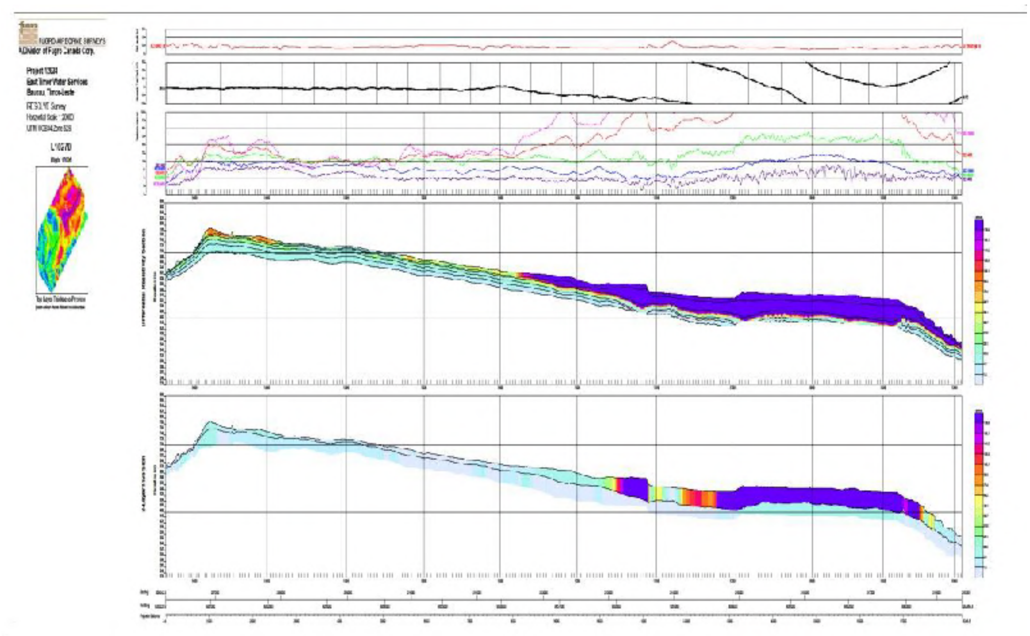

Figure 16 Flight Line 10270 (Fugro, 2012)

Figure 16 is the cross section along flight line 10270 oriented from south-west to north-east showing very thin limestone at highest point and changing abruptly to a thicker limestone in the middle of the section to the Baucau escarpment in the north. In this section there are three distinct dips in the bottom surface of the limestone suggesting drainage channels. (CSIRO offer an alternative interpretation that these may be fractures in the Viqueque Formation caused during tectonic uplift of Timor_Leste (pers. Com.)

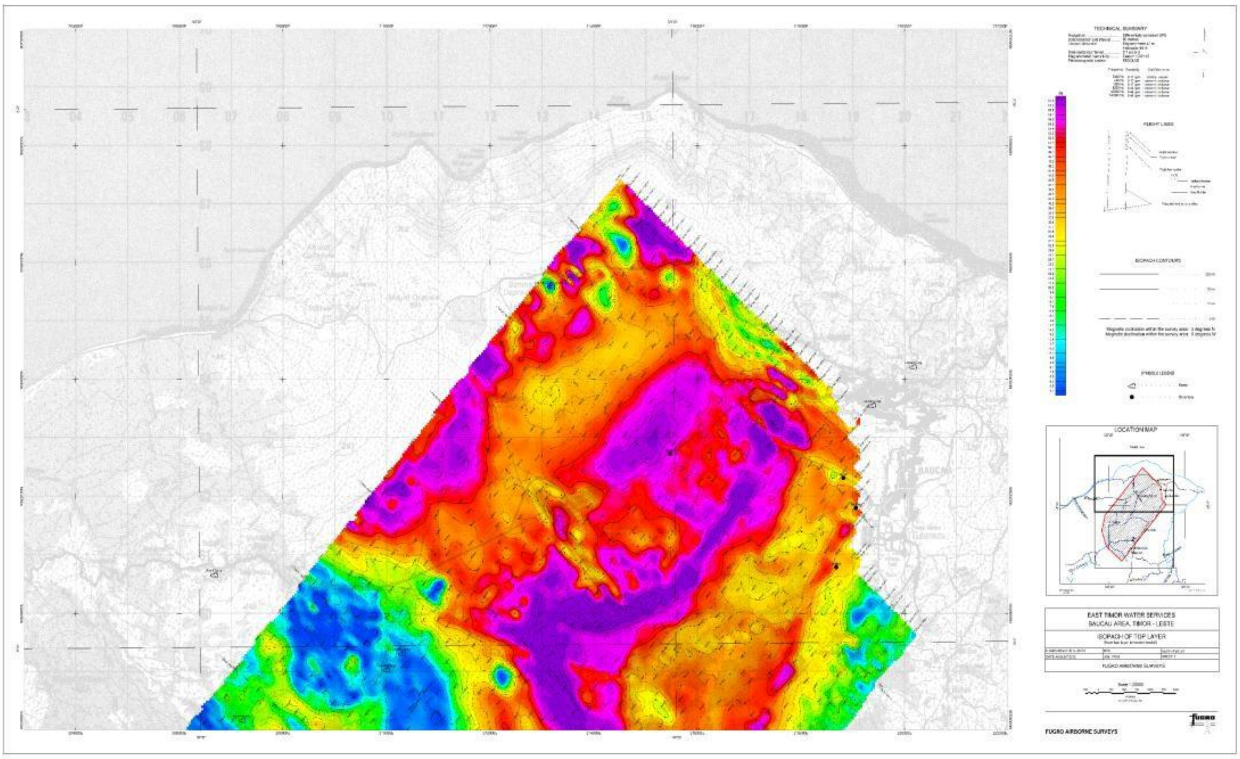

Figure 17 Isopach of Top Layer (north) (Fugro, 2012)

Figure 17 & Figure 18 show the interpreted thickness of the Baucau Limestone with purple the thickest and blue mostly absent (clay soil). The limestone shows a thick-terraced pattern. There are anomalous blue circles in the north suggesting sink holes in the limestone. One of these coincides with the large sinkhole (400 m diameter) known as Cekungan Baninau (Figure 20). The others can be recognized by the soil anomaly on satellite imagery.

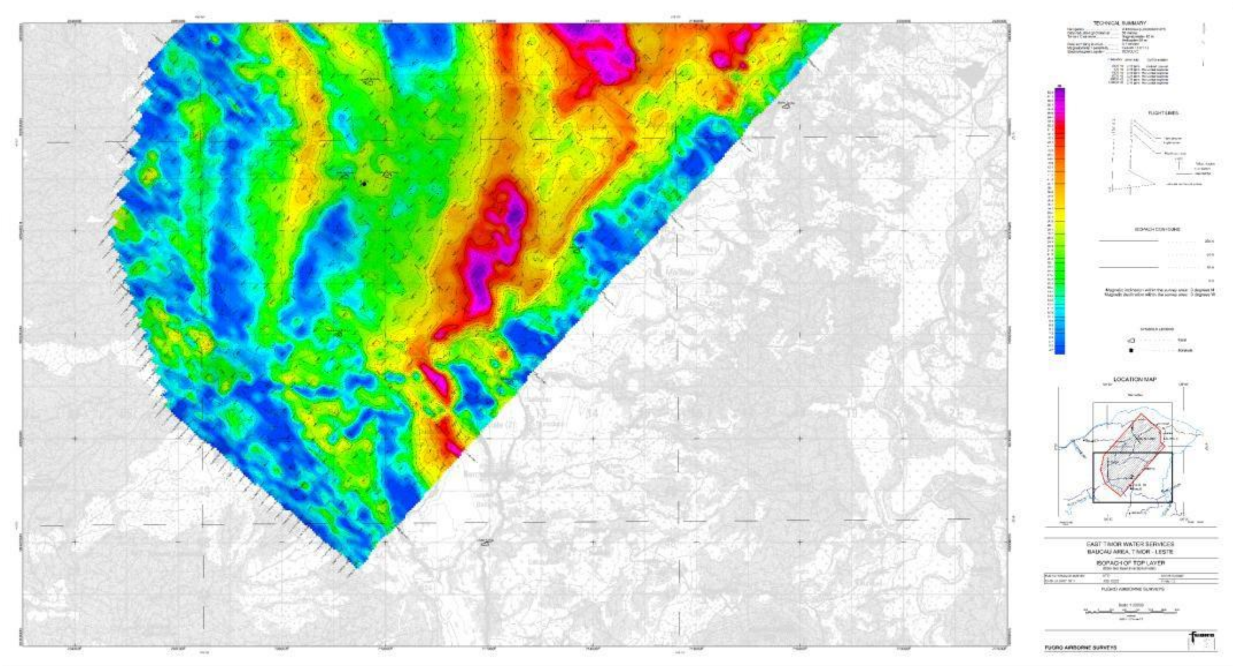

Figure 18 Isopach of Top Layer (south) (Fugro, 2012)

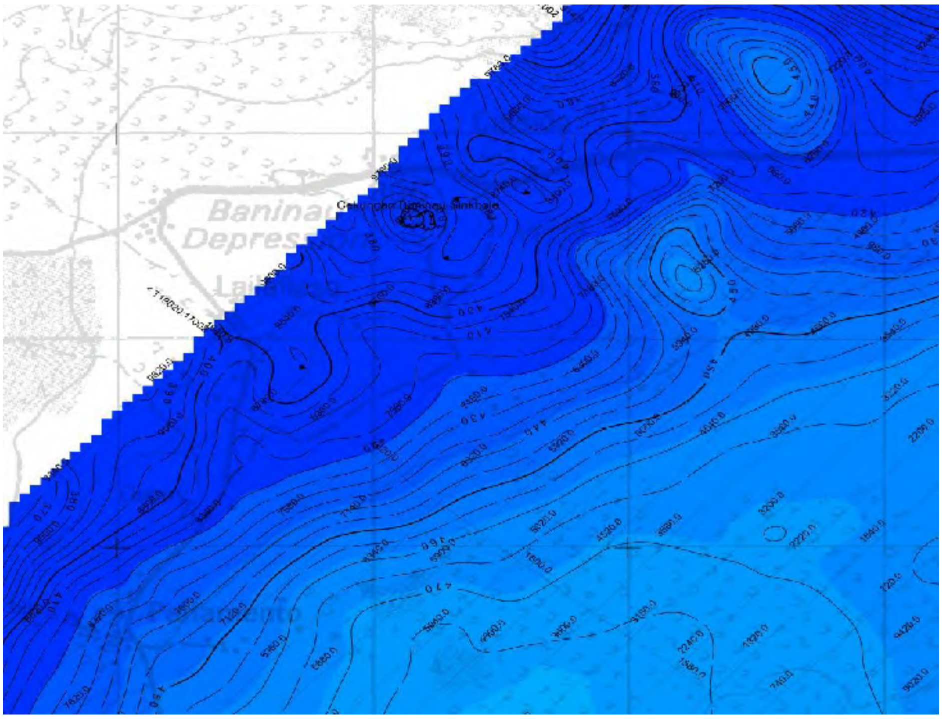

Figure 19 Cekungan Baninau (Fugro, 2012)

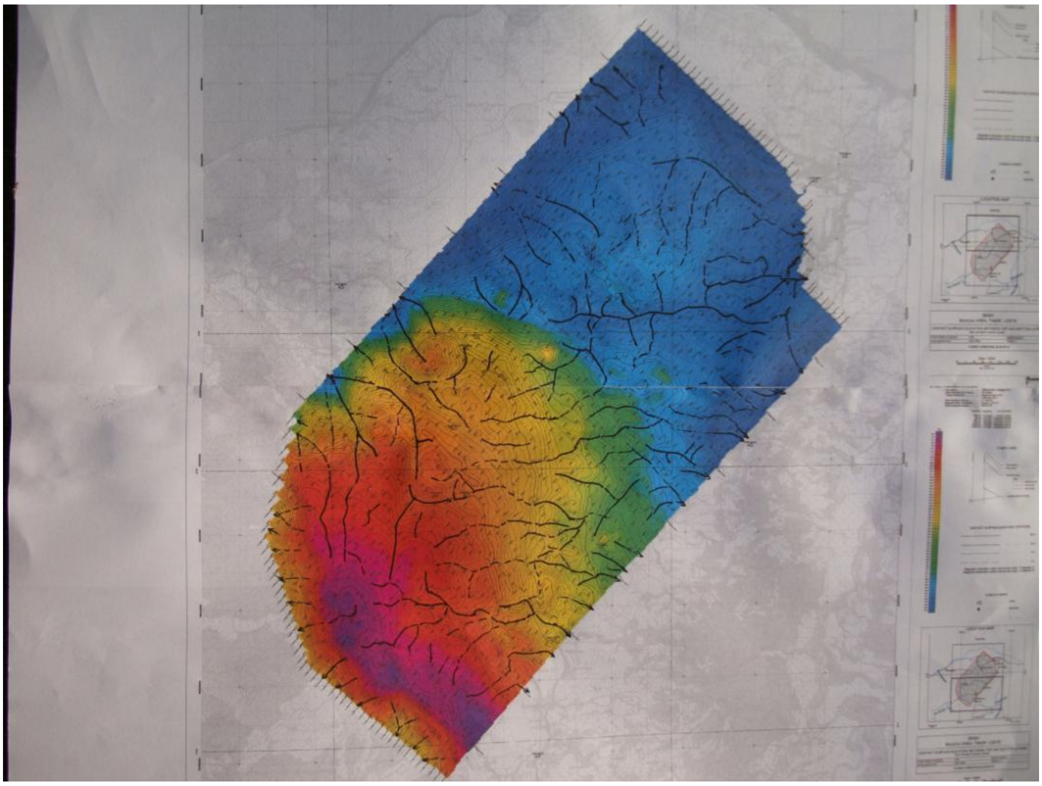

Figure 20 Interpreted Palaeo Drainage Channels (Furness, 2010)

Figure 20 is an interpretation of the inferred palaeo drainage channels from the inversion model of the data. These channels appear to flow in west to east direction or a north-westerly direction from a flow divide running roughly along the middle of the survey area oriented south-west to north-east. The channels also coincide with the known caves, canyons and springs and are therefore suggested as flow paths for the main discharge of the karst aquifer.

1.8 FLOW ESTIMATE

From the interpreted inversion model of the geophysical survey (Figure 20) it is estimated that approximately 10 km^2 collects recharge and drains towards the mine area. With an annual rainfall of 1,200 mm and an estimated recharge rate of 0.4 this is equivalent to 4.8 Gl/yr and is sufficient to meet the mine demand of 1.15 Gl/yr with sufficient through flow to meet village water supplies and environmental requirements. The pathway(s) of the water flow and flow rates of individual streams are not known. It is clear that recharge occurs across the plateau and that discharge occurs around the edges of the plateau where the limestone thins and springs surface.

Usage of the karst water occurs whenever there is a spring discharge that can be tapped. The water is used for domestic purposes and agriculture. There are no known successful bores in the karst area and only one bore in the alluvium at Karavelha. A multi-village water supply is pumped from the Uaileaveri Cave to the Triloca area. Mining in the proposed area could impact on discharge of springs and could introduce contaminants.

1.9 WATER QUALITY

The karst water is very fresh (Timor and WHO standards) and is suitable for all uses except for boiler where it will need treatment to remove calcium and possibly silica. A typical analysis of metals and metalloids from Uailia Spring at Baucau is:

Table 3 Water Quality Analysis, Uailia Spring, Baucau

Sample Description	Aluminium	Boron	Barium	Beryllium	Calcium	Cadmium	Cobalt	Chromium
	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Baucau Uidasime/Uailili Spring	0.01	<0.04	0.008	<0.0002	51	<0.004	<0.005	<0.004
Baucau Town Uailia Spring	0.01	<0.04	0.008	<0.0002	84	<0.004	<0.005	<0.004

Copper	Iron	Mercury	Potassium	Magnesium	Manganese	Molybdenum	Sodium	Nickel	Phosphorus
mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
< 0.005	0.007	<0.01	0.63	13	<0.001	<0.005	3	<0.005	<0.1

Lead	Sulphur	Antimony	Selenium	Silica	Tin	Strontium	Titanium	Vanadium	Arsenic	Zinc
mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
<0.01	3.2	<0.07	<0.04	8.2	<0.02	0.26	<0.004	<0.003	<0.04	<0.004
<0.01	1.2	<0.07	<0.04	6.1	<0.02	0.5	<0.004	<0.003	<0.04	0.009

(Timor and WHO applicable standards refer to Appendix 1 -)

A second more detailed analysis is provided from Caravelha Bore in Appendix 1 - . Showing water meets the standards, except for turbidity and coliform bacteria (treated by chlorine).

1.10 CAISIDU SPRINGS

Figure 21 Uaimatabai Spring

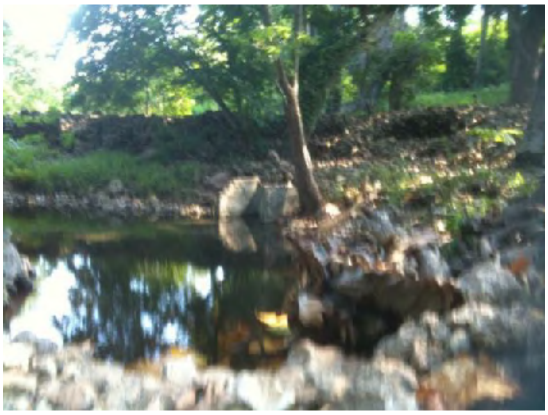

Figure 22 Uaisa Spring

The village of Caisidu lies at the northern end of the proposed Mine area 1.1. There are 4 sub-villages located close to the karst water springs. The karst water discharges below the main escarpment along a spring line, probably associated with a major fault in the Baucau Limestone. At highest elevation is the Uaimatabai Spring (Figure 21) emerging from a limestone cave (170 m elevation) along an overhang. The discharge is about 5 l/s and the water is fresh although probably hard.

The major spring discharge (142 m elevation) is located about 400 m downslope along the spring line. It is called the Uaisa Spring (Figure 22) and is close to the Caisidu School and surrounded by very tall breadfruit and rainforest trees. The discharge is approximately 10 l/s and the water is fresh at 633 µScm. Water is piped and run in open channels to the sub-villages at lower elevation. The third spring in the line is Uaiono (Figure 23) and this discharges into the sea at the proposed port area through a fracture in beach rock. It is only observed at low tide and is not practical as a water supply. The karst limestone probably discharges along the coast line, either below sea level or through alluvium and is thus not visible, except at this spring occurrence. The discharge of the spring is likely to be several litres per second and therefore negligible in the total groundwater resource calculation.

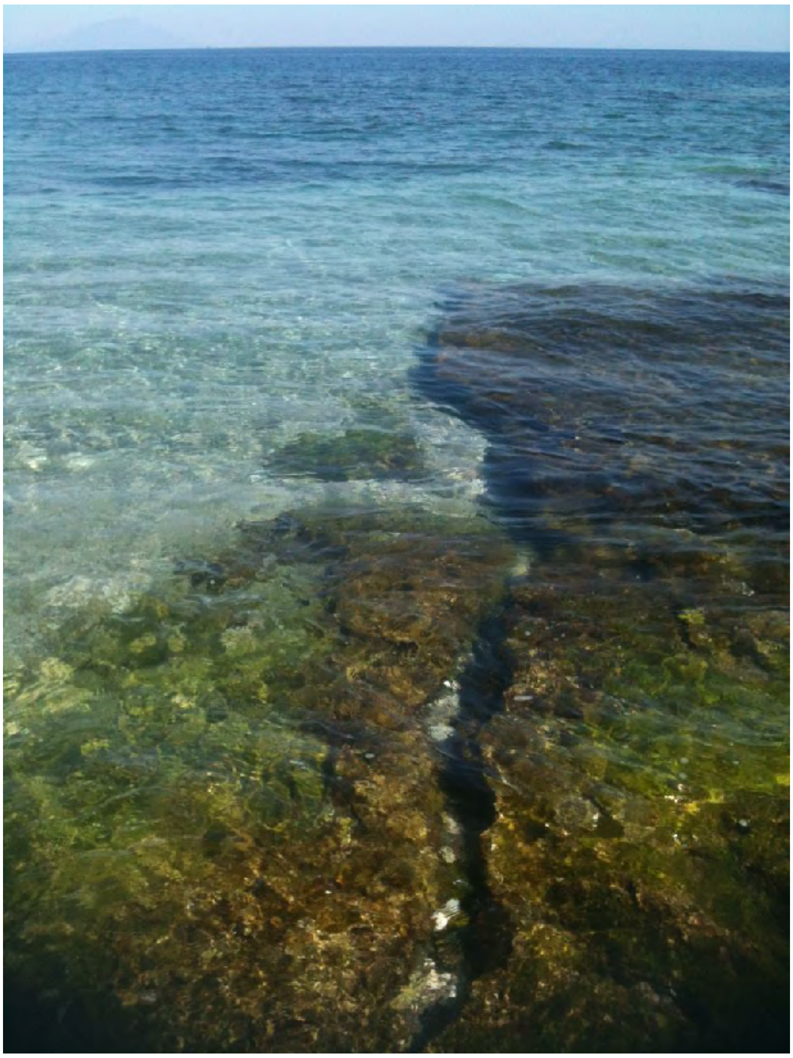

Figure 23 Uaiono Spring

1.11 COASTAL ALLUVIAL AQUIFER

The hydrogeology map (Figure 2) of Timor-Leste shows coastal alluvium in dark blue. From a survey of wells along the north coast it was found that the aquifer contains fresh water where there are significant rivers and karst water recharging the aquifer. Elsewhere, the aquifer is salty due to the limited recharge area, high evaporation and direct connection with the sea. Most of the alluvial aquifer in the vicinity of the proposed mine and cement plant is likely to contain fresh water based on monitoring of shallow wells near Caravelha and measurements of salinity in the coastal streams and swamps.

A review of borelogs from H2O Drilling revealed that the coastal alluvial aquifer near the Manulede River contains fresh water in gravel aquifers. A water supply bore for the village of Caravelha was constructed near the bridge over the Manulede River to a depth of 54 metres and the drilling log indicated two gravel layers separated by marine clay formations (Appendix 2 -). The water in the aquifer was fresh (743 µScm) and was tested by a step pumping test indicating a specific capacity of 1 l/s per metre of drawdown, establishing that the bore could continuously pump about 30 l/s. The bore is fitted with a pump capable of 10 l/s, but this is only used for about 1 hour per day to meet the needs of the small village of Caravelha.

Figure 24 Caravelha Bore at Manulede River

The Manulede River is quite extensive and drains the western side of the Baucau Plateau collecting the karst aquifer discharge. The river is approximately 14 km long with a catchment of roughly 100 km^2. It is concluded that the alluvial aquifer is recharged by the Manulede River and would be capable of supplying the water for the plant at 3.15 Ml/day or 35 l/s continuously without impacting on the village water supply, provided that sufficient separation (400 m) is made between bores. It is likely that the mine could use one bore for water supply and a second bore for backup (TC1 and TC2 Figure 25). The Manulede River is about 9 km from the proposed cement plant and this would necessitate a major pipeline. An alternative site has been located within 1 km of the site on the Uaidei River alluvium based on interpretation of satellite imagery and a field inspection together with an assumed similarity to the Caravelha bore site. .

Figure 25 Loction of Caravelha Bore Potential Plant water supply

A camp water supply may be possible close to the plant area on the Uaidei River at the location marked on Figure 26, if successful an additional 1 or 2 bores could supply the whole water demand. The Uaidei River was flowing at 10 l/s at the site at the time of inspection 06 May, 2015 with fresh water (409 µScm). During the dry season, this river is likely to stop flowing and aquifer salinity increase (additional monitoring will be required to ascertain the annual variability).The river is about 6 km long, originating upslope of Bucoli and has a catchment area of about 10 km^2.

Figure 26 Site for Camp Bore

1.12 IMPACTS OF THE PROJECT

The hydrogeological assessment and preliminary impact analysis is based on previous regional studies undertaken to date. No site specific downhole investigations and/or groundwater assessments have been undertaken as a part of the current study.

1.13 Potential Impacts of mining

The proposed mining method is by truck and shovels and is expected that it will be carried out down to the water table and may not impact on the groundwater. Figure 27 shows inferred groundwater flow paths around mine areas 1.1 and 1.2, however the exact locations are currently unknown. It is a feature of karst aquifers that contamination of the groundwater by spillage of pollutants (especially fuels) can occur very rapidly and the contaminants can be transported in hours or days to public water sources. Therefore, it will be necessary to adopt management procedures and strict protocols to prevent the spillage of fuels, lubricants and chemicals which could rapidly pollute public water supplies.

Figure 27 Inferred Groundwater Flow Paths

In mining area 1.1 it is possible that mining could impact the springs of the Caisidu four sub-villages if mining extends below the water table. The depth of water table is not known, but limestone core drilling indicates it could be greater than 100 metres. It is recommended that a Special Water Resources Reserve (Figure 28) be established at Caisidu to protect the sacred springs of Uaimatabai, and Uaisa, and the sacred trees surrounding the springs.

Figure 28 Special Water Resources Reserve

Mining area 1.2 is located on the northern part of the Baucau Plateau, to the north of the airport. The karst aquifer there flows to the west and to the north away from a groundwater mound near the airport. The discharge from the aquifer is in two springs (Wai Spring and Dubeti Spring in Figure 3) and beneath the sea. If mining proceeds below the water level, near the base of the limestone then the springs could be impacted.

Mining area 2 is located in the eastern part of the Baucau Plateau to the south of the airport. This is the most sensitive part of the karst aquifer as it supplies water to Baucau, and a number of villages, schools and college on the eastern side of the plateau. It also contains four known caves and numerous sink holes. This part of the karst aquifer has also been selected for future water supplies to New Baucau and the army camp at the airport.

Mining of area 2 would need to be preceded by investigations to clearly identify the major cave streams that supply water to the public and irrigated agriculture to prevent the disruption of these supplies or the contamination of the water. In some parts of this area, the karst water is known to be relatively shallow, at less than a few metres in some of the caves, and mining in these areas should be avoided.

1.14 Potential Impacts of Water Supply

The processing of clinker and the use of groundwater totals 1.15 Gl/year. It is calculated that this is about 25% of the annual recharge on the western side of the Baucau Plateau. If the mine water supply is taken from the discharge areas of the karst, i.e. from springs, there will be no impact on groundwater within the karst aquifer. However, if the water supply is obtained from water bores in the plateau region, i.e. at the Cekungan Baninau sinkhole area, then there may be an impact on certain spring discharge, provided those springs are physically connected to the aquifer and the karst features connected to the bores.

The impact of the water supply from the karst aquifer cannot be assessed by conventional hydrogeological methods (groundwater modeling) and other suitable methods will need to be applied. The use of dye tracing is a suitable method to positively identify the connection of karst features such as cave streams and springs as has been demonstrated in the Baucau Plateau.

Obtaining the required water supply from the coastal aquifer is considered a better option than from the karst aquifer due to predictable impacts that do not affect other users, springs and groundwater dependent ecosystems. If possible, this should come from the Camp Bore Site (Figure 26) subject to water quality and quantity. It is likely that 2 to 3 bores will be required at 400 m intervals along the river valley. An alternative is the Caravelha bore area, where supplies have been tested, but this would necessitate a 9 km pipeline. The radius of impact would probably be less than 200 metres from each bore and therefore not impact on other users.

Appendix 3 - shows the groundwater receptors that may be potentially impacted from the proposed development. .

2. RECOMMENDED ACTION

Based on the study the following recommendations are made: :

- Two test bores (200 mm nominal casing) be drilled at the Camp site at spacing of 400 m and each to a depth of 50 m. Upon satisfactory completion of the bores, test pumping should be performed including a 4 step increasing pumping rate test (4 hours) and a minimum of 24- hour constant rate test with observations of water levels and flow rates. Water quality should be monitored during the test and water samples taken at the end of pumping. Water level recovery should be measured until 80% recovery. Water level and water quality should be monitored by data loggers and probes at hourly intervals.
- A water monitoring program should be established at Uaisa and Uaimatabai Springs measuring flow rate and water quality at 3 month intervals.
- A Special Water Resource Reserve be declared around the Uaisa and Uaimatabai Springs and the associated sacred trees. This should be clearly signed posted and marked with survey pegs and fluorescent paints. No mining activity should occur within this reserve or upslope.
- This study has been a preliminary statement on the impact of mining on groundwater. For the karst aquifer little is known about the depth and flow patterns of karst water. Therefore, it will be necessary to have an ongoing study to review mining plans and to monitor water depths and water quality.
- The mining plans will need to demonstrate that mining is not occurring upslope of the springs that supply village water, to prevent loss of supplies and accidental contamination.
- The underlying imperative is that mining does not continue below the water table as it occurs during the wet season. Therefore, as mining progresses each water intersect needs to be noted and mapped on a progressive update of karst conditions.
- Mining should not proceed deeper than the water cuts and water quality monitoring established at each water cut.

3. REFERENCES

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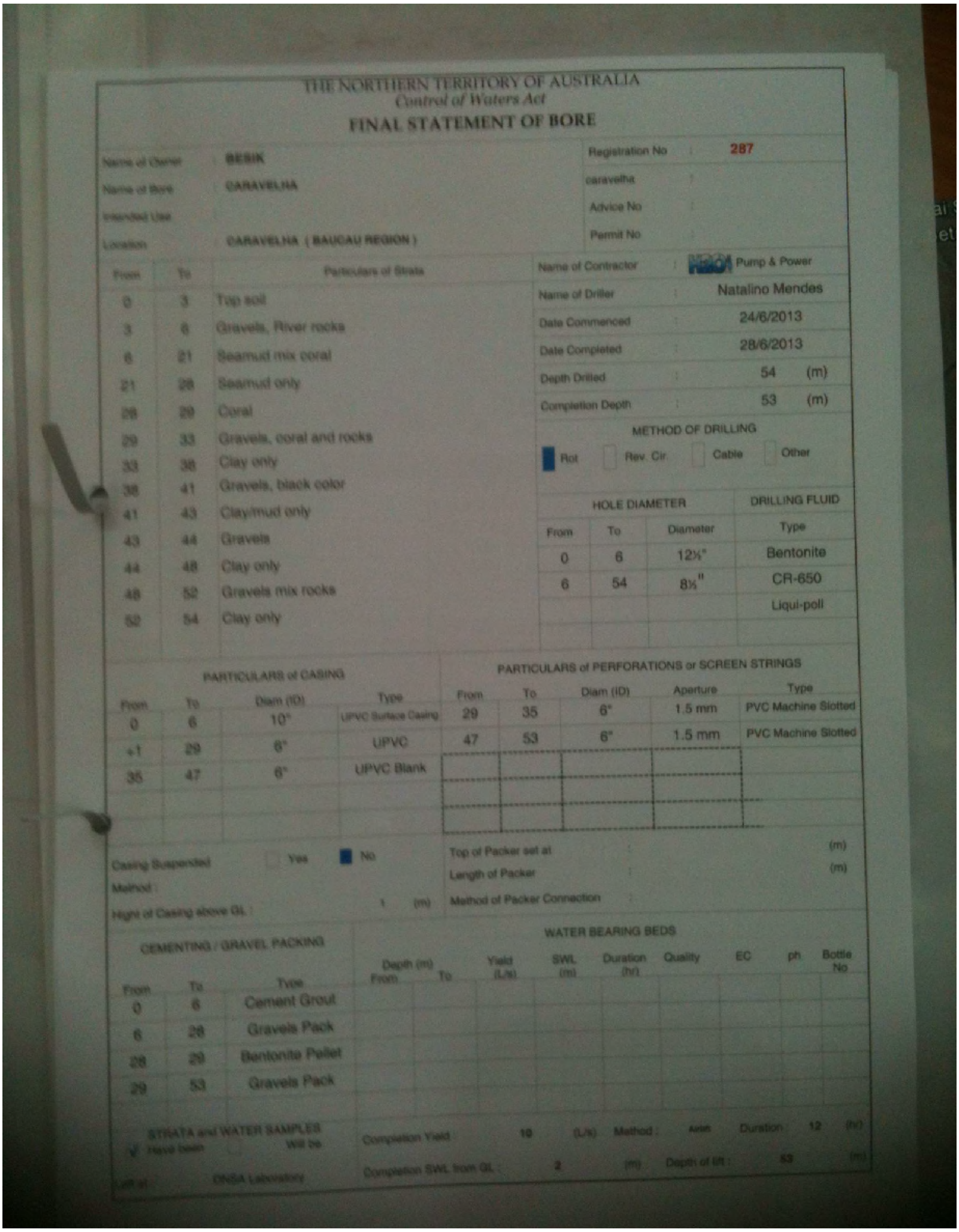
Appendix 1 - KARST WATER QUALITY

WorleyParsons Consulting

TL CEMENT, LDA
BAUCAU CEMENT PROJECT
PRELIMINARY GROUNDWATER STUDY

Sample Location	Sample No.	Cond	pH	Total Hardness	Temp Hardness	Alkalinity	Residual Alkalinity	Total Ions	TDS	Colour	Turbidity	pH Sat	Saturation	Mole R	SAR	FMR	Na+	K+	Ca++	Mg++	H+	HCO3-	CO3--	OH-	Cl	F-	NO3-	SO4--	Fe	Mn	Zn
Baucau Uailili	TIM1	364	8.2	183	173	173	0	293	196	<1	<1	7.5	0.7	0.4	0.1	24	4	0.7	51	13	0	207	2	0	2.8	0.94	0.5	10.2	<0.01	<0.01	<0.01
Baucau Uailia	TIM2	429	7.72	218	209	209	0	360	238	<1	1	7.2	0.5	1	0.1	24	4	0.7	85	1.5	0	253	0.8	0	4.6	0.11	6.1	3.9	<0.01	<0.01	<0.01

Appendix 2 - CARAVELHA BORE RN 287



THE NORTHERN TERRITORY OF AUSTRALIA
Control of Waters Act

FINAL STATEMENT OF BORE

Name of Owner	BESIK	Registration No :	287
Name of Bore	CARAVELHA	caravelha :	
Intended Use		Advice No :	
Location	CARAVELHA (BAUCAU REGION)	Permit No :	

From	To	Particulars of Strata
0	3	Top soil
3	6	Gravels, River rocks
6	21	Seamud mix coral
21	28	Seamud only
28	29	Coral
29	33	Gravels, coral and rocks
33	38	Clay only
38	41	Gravels, black color
41	43	Clay/mud only
43	44	Gravels
44	48	Clay only
48	52	Gravels mix rocks
52	54	Clay only

Name of Contractor :	H2O Pump & Power
Name of Driller :	Natalino Mendes
Date Commenced :	24/6/2013
Date Completed :	28/6/2013
Depth Drilled :	54 (m)
Completion Depth :	53 (m)

METHOD OF DRILLING

■ Rot ☐ Rev. Cir. ☐ Cable ☐ Other

HOLE DIAMETER			DRILLING FLUID
From	To	Diameter	Type
0	6	12¼"	Bentonite
6	54	8¼"	CR-650
			Liqui-poll

PARTICULARS of CASING

From	To	Diam (ID)	Type
0	6	10"	UPVC Surface Casing
+1	29	6"	UPVC
35	47	6"	UPVC Blank

PARTICULARS of PERFORATIONS or SCREEN STRINGS

From	To	Diam (ID)	Aperture	Type
29	35	6"	1.5 mm	PVC Machine Slotted
47	53	6"	1.5 mm	PVC Machine Slotted

Casing Suspended ☐ Yes ■ No

Method :

Hight of Casing above GL : 1 (m)

Top of Packer set at : (m)

Length of Packer : (m)

Method of Packer Connection :

CEMENTING / GRAVEL PACKING

From	To	Type
0	6	Cement Grout
6	28	Gravels Pack
28	29	Bentonite Pellet
29	53	Gravels Pack

WATER BEARING BEDS

Depth (m) From	To	Yield (L/s)	SWL (m)	Duration (hr)	Quality	EC	ph	Bottle No

STRATA and WATER SAMPLES

√ Have been ☐ Will be

Left at : DNSA Laboratory

Completion Yield 10 (L/s) Method : [illegible] Duration 12 (hr)

Completion SWL from GL : 2 (m) Depth of lift : 53 (m)

MINISTÉRIO DAS OBRAS PÚBLICAS
SECRETARIADO DO ESTADO
ÁGUA, SANEAMENTO E URBANIZAÇÃO

DIRECÇÃO NASIONAL DOS
SERVIÇOS DE ÁGUA (DNSA)

Request for Water Quality Testing

Sample analysis reference : 000003857
Requesting Organization : H_2O PUMP & POWER
Description of the organization: H_2O DRILING COMPANY
Contact Person : Ms. OVY | Telephon : 77236399
On behalf of organization, I agree to pay the cost of test request below: Signature: √
Data and time sample was taken : 24/07/2013 | Date and Time sample was received: 24/07/2013
Sample location specification : BAUCAU / CARABELA
Water Source: River | Mountain stream | Spring | Well √ | Others
Sampled by : Ms. OVY | Received in laboratory by: MARIO SOARES
Approved to test by: ESTELA SALDANHA

Cost (US$)	Parameter	Unit	Request test	Result	WHO/East Timor Guideline	Testing method
Physical test						
1.00	pH value	-	√	8.4	6.5-8.5	pH Meter
1.00	E.conductivity	(µs/cm	√	743	NS	Conductivity meter
1.00	TSS	(mg/L)	√	0.06	NS	Gravimetry
1.00	TDS	(mg/L)	√	372	1000	Gravimetry
1.00	Salinity	(‰)	√	0.4	NS	Conductivity meter
1.00	Temperature	(°C)	√	23.7	NS	Conductivity meter
1.00	Turbidity	NTU	√	**49.6**	5 (NTU)	Turbidity meter
Chemical test						
2.00	NH_3-N	mg/L	√	0.6	1.5	Spectrophotometer
2.00	NO_3-N	mg/L	√	0.2	10 (as NO_3-N)	Spectrophotometer
2.00	NO_2-N	mg/L	√	0.030	1 (as NO_2-N)	Spectrophotometer
1.00	Iron (Fe)	mg/L	√	0.2	0.3	Spectrophotometer
2.00	Manganese (Mn)	mg/L	√	0.5	0.5	Spectrophotometer
1.00	Fluoride	mg/L	√	1.1	1.5	Spectrophotometer
2.00	Free chlorine	mg/L	√	ND	0.5	Comparator,
2.00	Ca.hardness	mg/L	√	220	NS	Titration
2.00	Arsenic	mg/L	√	ND	0.01	Comparator
2.00	T. Hardness	mg/L	√	**260**	200	Titration
2.00	Total alkalinity	mg/L	√	280	NS	Titration
2.00	Sulphate (SO_4^{2-})	mg/L	√	120	250	Spectrophotometer
Bacteriological test						
16.00	Total Coliform	CFU/100mL	√	TNC	0	Membrane filtration
16.00	E.Coli	CFU/100mL	√	0	0	Membrane filtration

Total cost	Remark	
$.61.00 USD	**- Total Coliform is problem !** **- Turbidity, T. Hardness is high !**	Inspected by: Head of DN-SA Laboratory

Legend: 1. NS: not set; ND: not detectable; NT: not tested; NR: not result; CFU: Colony Formed Unit; TNC: too numerous to count.

Appendix 3 - GROUNDWATER CENSUS

Feature Name/ Potential Receptors	Type	Latitude	Longitude	Location	Significance	Figure reference (if applicable)
Waiono Spring	Spring	8.44819	126.345360	Proposed Port Area	Brackish water spring flowing to the ocean	23
Uaisa Spring	Spring	8.447002	126.358069	< 100m from the mining area	Local water supply for villages of Caisidu and 4 sub-villages within 100m	22
Uai Matabai	Spring	8.447480	126.361462	< 100m from the mining area	Local water supply for villages of Caisidu and 4 sub-villages within 100m	21
Cekungan Baninau Sinkhole	Sinkhole	8.444532	126.395214	3km east of the mining area	Possible major recharge area, no development of karst water	27
Wai Spring	Spring	8.434049	126.386989	3km north-east of the mining area	Karst discharge used for several houses, most likely connected to Cekungan	27

Feature Name/ Potential Receptors	Type	Latitude	Longitude	Location	Significance	Figure reference (if applicable)
					Baninau Sinkhole	
Dubetu Spring	Spring	8.4344049	126.386989	3km north-east of the mining area	Karst discharge used for several houses most likely connected to Cekungan Baninau Sinkhole	27
Camp Bore	Borehole	8.456221	126.332647	1km west of the mine area	River alluvium Potential source of water supply for the project	27, 26
Manulede Bore	Borehole	8.489722	126.256778	>5km west of the mine area	Water Supply bore in the Manulede River Alluvium Local water source for Karavelha village and sub-villages	25

Feature Name/ Potential Receptors	Type	Latitude	Longitude	Location	Significance	Figure reference (if applicable)
Huhadili Cave	Cave	8.5054	126.3852	>5km south of the mine area	Appears to be not connected to any of the monitored springs locally	3
Uaileamata Cave	Cave	8.5403	126.3585	>5km south of the mine area	Connected to Ulaleaveri Cave, Uaililea spring and ultimately, to Uainoi Spring, located >10km from the mine area 1	3
Ulaleaveri Cave	Cave	8.5262	126.3913	>5km south of the mine area	Connected to Uaililiea Spring which feeds into Uainoi Spring, which is >10km from the mine area 1	3
Uaimatahun Cave	Cave	8.5581	126.3579	>5km south of the mine area	Connected to Uainoi Spring, >10km from the mine area 1	3

Feature Name/ Potential Receptors	Type	Latitude	Longitude	Location	Significance	Figure reference (if applicable)
Uainoi Spring	Spring	8.5528	126.3991	>10km south of the mine area	Water source for irrigation area	3
Uaililea Spring	Spring	8.5157	126.4398	>10km south of the mine area	Water source for several villages around Gariuri	3

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Appendix 5 Vegetation and Fauna Survey Report


BAUCAU CEMENT CLINKER PLANT VEGETATION AND FAUNA SURVEY

Colin R. Trainor & Brett Easton

Report to WorleyParsons, August 2015






Acknowledgements

Thanks to Cypriano Belo (Aldeia chief of Lia Lai Leso), Manuel Freitas (Aldeia chief of Parlamento), Pedro da Costa (Aldeia chief of Osso-wa), Carlos Assis Bento (Aldeia chief of Cai-Sidu) in the village of Tirilolo for field help at the Jetty, Plant and Mine. We also thank Daniel Correia and Alexandre Boavida for help in the field at Wailicama.

Thanks to Kyle Armstrong of Specialised Zoological for identifying bat calls and preparing a report (cited here as Armstrong & Konishi 2015; and included here as Appendix 9) on the bats of the study area; Hinrich Kaiser for identifying several lizards and Vince Kessner for provisional identification of landsnails. Thanks also to Daniel Hunter and Oktavio Araujo for facilitating field contacts and other help in preparing for fieldwork.

Contents

Summary

Background: Preliminary environmental studies were conducted during May 2015 at four study sites associated with a proposed cement mine and plant in the village areas of Tirilolo and Wailicama, near Baucau, Timor-Leste. The sites were: Jetty (0.05km^2), Plant Site (1 km^2), Mine I-I (5.76 km^2) and Clay Mine (4.0 km^2). Local community members assisted with all aspects of the field survey. The main potential environmental impacts made during construction and development of the mine would include site clearing, levelling and excavation causing loss or disturbance to native vegetation and habitats, and associated loss of habitat for native wildlife.

Methods: The vegetation assessment included surveys of a combination of initial random points within the key test sites that were then further expanded to include any different neighboring vegetation assemblages based on direct field observations. The vegetation assessment focused on systematic survey of each survey site using quadrats (25m x 25m= 625m^2). In total 22 different quadrat sites were sampled over 13,750m^2. Within each quadrat sample, the dominant vegetation types were assessed and sampled at the upper, middle and lower stratums. Additional information recorded at each site included disturbance, basal area, height range, weed-introduced species abundance, canopy cover, litter cover, gravel extent, bare earth and soil types. At a floristic level, any unusual plant specimens that could not be identified in the field were also collected for identification later. Vegetation assemblages were described in terms of "structural formations". Fauna survey consisted of general observations, informal interviews with local field assistants, a total of 24-10 minute point count searches and counts of birds, reptiles, amphibians and mammals; nocturnal spotlighting and Acoustic bat recording. Fauna habitat assessment was done at each point count including measuring or estimating fauna habitat (canopy cover, vegetation structure, rock cover, litter cover, presence of logs, caves, rock outcrops and other significant fauna habitat features). The quality of fauna habitat was subjectively assessed as either Low, Moderate or High for each point count site.

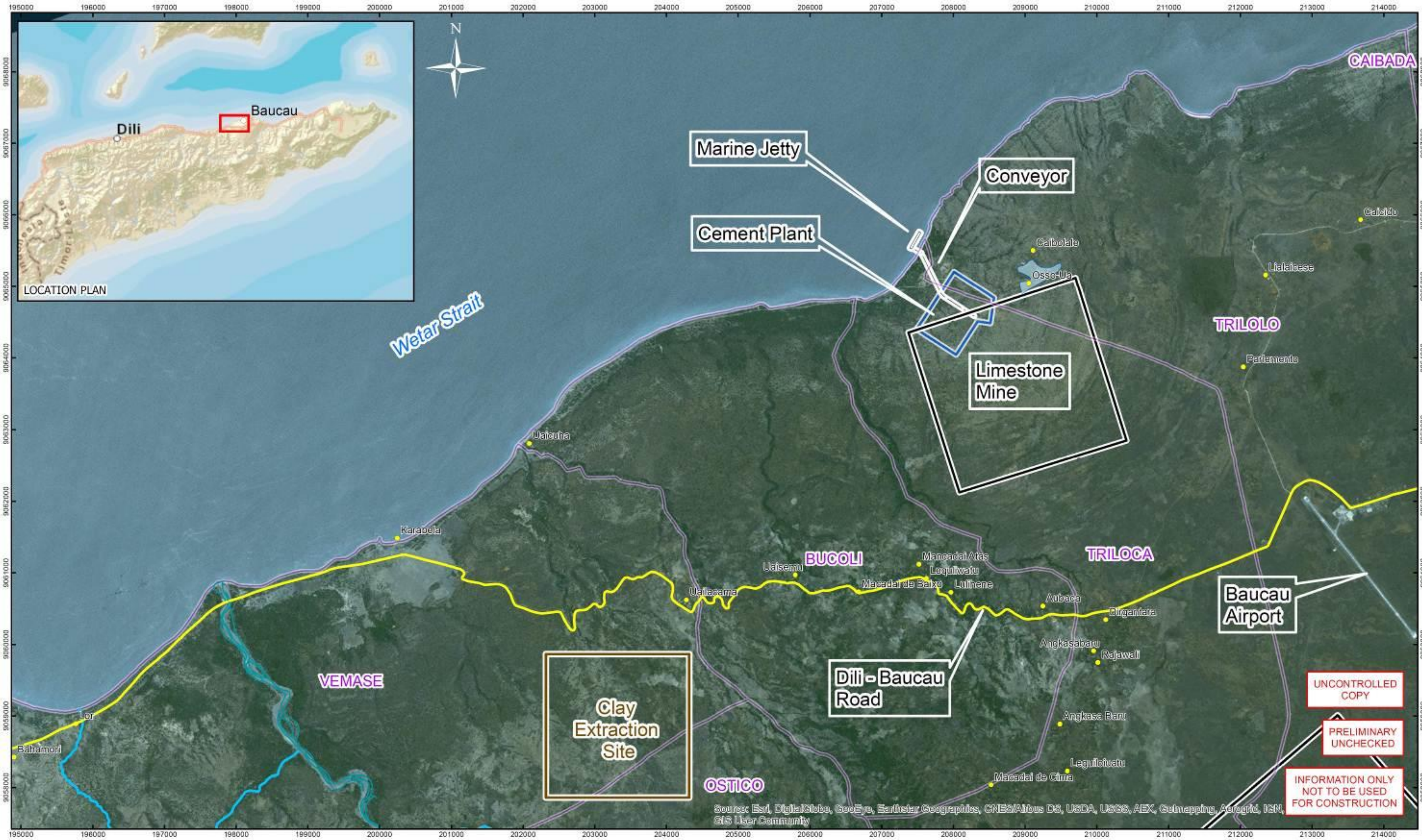
Results:

Local land use at the study sites included housing, small-holder agricultural plots, livestock grazing and hunting. The presence of old stone fences on the mine (in open woodland) and at the Clay mine in Closed tropical forest was evidence of long-term agricultural landuse (at least 50-100 years previously) and of significant regeneration of tropical forest at the Clay mine site. There are no protected areas or Important Bird Areas identified in or near the study areas, and a gap filing exercise did not identify any national priority sites in or near the study areas. The key vegetation structural formations surveyed can be broadly described as either Closed Tropical Forest systems or open woodland systems. The Closed Tropical Forest systems predominantly occurred in the drainage lines, gullies and more sheltered areas and exhibit a higher soil moisture level, compared to the adjacent open woodland. At the mine and plant sites the majority of the Closed Tropical Forest occur as small isolated patches in gullies dominated by *Peltophorum pterocarpum*. The Clay mine site had significantly more extensive contiguous Closed Tropical Forest, particularly on the eastern side of the site. These areas were not however uniform vegetation assemblages but rather variants, including bamboo forest areas, reflecting the influence of elevation, soil, aspect and past and present-day land uses.

A total of 71 plant species were identified during the survey including three species of conservation concern listed under the IUCN Red List as Vulnerable. These were Sandalwood (*Santalum album*) recorded at the Mine in Open forest and Closed Tropical Forest, Rosewood (*Pterocarpus indicus*) recorded at Clay Mine in Closed Tropical Forest and Borneo Teak (*Intsia bijuga*) also recorded at the Clay mine in Closed forest. These three trees and an additional four plant species are listed as "protected" on the Timor-Leste draft Interim List of Protected species, and a further four species are listed as "Alien" – or weeds - on the Interim List of prohibited Invasive species.

A total of 87 vertebrate fauna species were recorded including two amphibians (an undescribed species of Rice Paddy Frog *Fejervarya* sp 1 and the introduced Black-spined Toad *Bufo melanostictus*), eight reptiles including two apparently undescribed *Carlia* skinks (*Carlia* sp 'lowland' and *Carlia sp* 'Baucau') and four other native species, 22 mammals (10 insectivorous echolocating bats [microchiropteran], one fruit bat [megachiroptera], two native terrestrial species and nine introduced or livestock species) and 56 bird species (all native). A total of 10 different bat call types (=species) was distinguished, and four of these call types could be allocated to a species through comparison with available unpublished reference calls. Three landsnail taxa were also collected.

Study area



LOCATION PLAN
Dili
Baucau
N
Wetar Strait
Marine Jetty
Conveyor
Cement Plant
Limestone Mine
Clay Extraction Site
Dili - Baucau Road
Baucau Airport
CAIBADA
TRILOLO
TRILOCA
BUCOLI
VEMASE
OSTICO
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PRELIMINARY UNCHECKED
INFORMATION ONLY NOT TO BE USED FOR CONSTRUCTION

To provide national context for vertebrates these results represent c.33% of the amphibians known from Timor-Leste, 16% of the reptiles, c.42% of the mammals and 44% of the resident landbirds (excluding waterbirds, migrant and visiting birds) known from Timor-Leste. One reptile (Tokay Gecko *Gekko gecko*), four echolocating bats and 27 bird species are listed on the Timor-Leste draft Interim List of Protected species. The Black-spined Toad is the only fauna species listed as "Alien" on the Timor-Leste draft Interim List of prohibited Invasive species.

Table. Summary of vegetation communities, flora and fauna species of conservation significance at the study sites.

Main Vegetation communities	**IUCN status**	**Sites**			
		Jetty	**Plant**	**Mine**	**Clay**
Closed tropical Forest	Na		Limited extent; good condition	Limited extent; good condition	Extensive; good to excellent condition
Open Woodland	Na		Extensive; degraded to good condition	Extensive; degraded to good condition	Extensive; highly degraded to good condition
Palm forest/beach forest	Na	Present; degraded			
Agricultural land/ricefields	Na	Present		Present	extensive
Plant species					
Sandalwood *Santalum album*	Vulnerable			X	
Rosewood *Pterocarpus indicus*	Vulnerable				X
Borneo Teak *Intsia bijuga*	Vulnerable				X
Fauna					
Rice Paddy Frog *Fejervarya* sp 1 [c.f. Kaiser *et al*. 2011]	?				X
Carlia sp 'lowland' [c.f. Kaiser *et al*. 2011]	?	X			
Carlia sp 'Baucau' [c.f. Kaiser *et al*. 2011]	?		X	X	X
Canut's Horshoe Bat *Rhinolophus canuti*	Vulnerable	X		X	X
Kai Horseshoe Bat *Rhinolophus celebensis*	Data Deficient	X			X
Pink-headed Imperial Pigeon *Ducula rosacea*	Near threatened				X
Olive-shouldered Parrot *Aprosmictus jonquillaceus*	Near threatened			X	X
Cinnamon-banded Kingfisher *Todiramphus australasia*	Near threatened		X	X	X
Orange-sided Thrush *Geokichla peronii*	Near threatened			X	X
White-bellied Bush Chat *Saxicola gutturalis*	Near threatened			X	X
Timor Sparrow *Lonchura fuscata*	Near threatened		X	X	X

Birds dominated the systematic point count surveys with 284 of the 315 independent fauna records (species x point counts). There was a single point count record of an amphibian (Black-spined Toad), 21 independent point count records of reptiles, and just six point count records of mammals (all livestock or Timor Deer *Cervus timorensis*). There were only two observations of Rice Paddy Frog at the Clay Mine. The two undescribed *Carlia* skink species were recorded widely. The results were typical of open woodland habitats in lowland ecosystems of Timor-Leste, with records of about half the resident landbird species of Timor. A large proportion of the recorded fauna, especially among amphibians, reptiles and mammals consisted of introduced/tramp or invasive non-native species. The invasive and toxic Black-spined Toad has been implicated in the decline of a range of herpetofauna species, and common introduced geckos such as Tokay Gecko (*Gekko gecko*) and House Gecko (*Hemidactylus frenatus*) may be similarly involved in decline of native gecko species. Livestock species such as Water Buffalo, Banteng/cattle, horse and sheep were regularly observed at the Mine and Clay mine sites and obviously impacted the quality of vegetation and fauna habitat through grazing and dispersing invasive weeds.

Extensive Closed Tropical Forest at the Clay mine was important habitat for Near threatened, restricted-range and forest specialist bird species. All forest specialized bird species recorded at the Jetty, Plant and Mine were also recorded at the Clay mine, but 14 forest specialist bird species were only recorded at the Clay mine, highlighting the conservation significance of tropical forest at this site. This included six bird species listed by the IUCN as Near threatened. Of particular interest were records of the IUCN Near threatened Pink-headed Imperial Pigeon *Ducula rosacea*, a large forest specialized pigeon which is threatened by hunting and forest loss in Timor-Leste. The Indonesian Short-nosed Fruit Bat and 10 insectivorous bat species were recorded, and local villagers reported that Long-tailed Macaque (*Macaca fascicularis*) was present at the Plant, Mine I-1 and Clay Site.

Many flora and fauna species would be absent from the study areas because they have small distributions in Timor-Leste, through lack of specific habitat features while other taxa may need specialized survey techniques to record their presence.

Recommendations: The main impacts of the proposed project will include conversion and loss of vegetation communities, removal of trees and conversion of habitat for fauna species. We found that the *Eucalyptus alba* and Ceylon Oak *Schleichera oleosa* dominated woodlands on the Mine and Plant was generally in good condition, but compared to Closed Tropical Forest are clearly not as biologically significant. Woodland or open woodland communities occur widely in Timor-Leste, perhaps covering c. 3,983km^2 of the nation and woodlands dominated by *Eucalyptus alba* are relatively restricted covering c.5-7% of the country (<c.600 km^2). The status of *Eucalyptus alba* woodland in Timor-Leste remains little known but may need further consideration given that the species occurring in Timor-Leste is apparently different from populations occurring in northern Australia.

Closed Tropical Forest in the Mine, Plant and Clay sites hosts IUCN listed threatened tree species, the globally Vulnerable Canut’s Horshoe Bat *Rhinolophus canuti* and Near threatened, the Data Deficient Kai Horseshoe Bat *Rhinolophus celebensis* and forest specialized bird species. Key threats to Canut’s Horshoe Bat and Kai Horseshoe Bat would include disturbance at cave roosts, loss of roosts, and loss of optimal foraging habitat through clearing of forest. Up to a maximum of eight out of ten echolocating bat species recorded during the survey use caves for daytime roosting. Aggregations of cave roosting bats are vulnerable to disturbance and increased rates of mortality in these refuges.

Closed Tropical Forest in the survey sites is of high biological significance despite historical and ongoing human use. In Timor-Leste the loss or conversion of Closed Tropical Forest is the prime driver of decline in populations of forest trees, IUCN listed Near threatened forest birds at least. Ensuring that Closed Tropical Forest habitats in the Clay Mine are not cleared would be the most important action to minimize risk from the project. Similarly, where possible maintenance of the small patches of Closed Tropical Forest mapped in the Mine and Plant areas would also be valuable.

Background

An Environmental Impact was requested for a proposed Cement Project in the vicinity of Bucoli, Bacau sub-district, Baucau Municipal, Timor-Leste. Details of the proposed development and potential environmental impacts are described in a project document by TL Cement LDA (2014). The proposed construction is for a 1.65 million tonnes per annum capacity cement project. The TL Cement LDA (TLC) Plant is proposed to be located in Suco (village) Tirilolo, Aldeia Ossoolla near Baucau in Baucau sub-district, about 120 km east of Dili, Timor-Leste.

There are five main sites: 1) Jetty is a coastal site in Suco Tirilolo; 3) Plant site in Suco Tirilolo; 4) Mine (Bucoli North Area 1 [Mine I-1]) in Suco Tirilolo is proposed as the source of limestone, and 5) Clay mine is located in Suco Wailicama and is proposed as the source of clay.

The main potential environmental impacts will be made during construction and development of the mine. In this report we are largely considering terrestrial environments roughly to the low tide mark:

- Site clearing, levelling and excavation (Jetty including conveyor belt, Plant, Mine and Clay Mine): disturbance or loss of native vegetation and habitats and associated loss of habitat for native wildlife.

The Operation phase of the Proposed cement plant will mainly consist of the following activities (TL Cement LDA (2004):

- excavation of limestone, sandstone and clay from the captive mines;
- Crushing of limestone, sandstone and clay;
- Transportation of limestone from mine/s to plant;
- Transportation of other correctives to the plant site;
- Preparation of raw meal by adding correctives to limestone;
- Clinkerisation of raw meal;
- Cooling and heat recovery;
- Blending and grinding of clinker by adding additives;
- Packing and dispatch;
- Ship traffic;
- Transportation of raw material like coal, additives etc to plant by belt conveyor;
- Transportation of outbound clinker by belt conveyor.

Field surveys were required for 4 main sites:

1. Jetty (0.05 km^2)
2. Plant site (1 km^2)
3. Mine I-1 (5.76 km^2)

4. Clay mine (4 km^2)

The following report is based on field surveys at the project sites during c. 20-26 May 2015. It includes an assessment of the potential environmental impacts of the proposed development of the mine on vegetation communities and fauna.

Limitations to interpretation of biological surveys in Timor-Leste

There is no national mapping of vegetation communities, and there are very few site-specific surveys of vegetation communities that are useful for comparisons. This makes it difficult to characterize the relative biological importance of vegetation types. The IUCN has assessed the conservation status of plant and fauna species which have been described, but undescribed species have not yet been assessed. Of the c.60 amphibian and reptiles species recorded to date from Timor-Leste, approximately 26 (43%) are yet to be described (O'Shea *et al.* 2015). Additionally there are undescribed species of, at least, shrews, rodents (extinct and possibly extant taxa) and bats. Very little is known of the national distribution and habitat use patterns of these species. Among fauna groups birds are the richest and by far the best known, with relatively detailed information on distribution, habitat use and status (via IUCN and national) available.

While the global conservation status of some plant and fauna species occurring in Timor-Leste have been assessed, there is no national biodiversity database or Atlas scheme, and no formal Timor-Leste assessment of the conservation status of vegetation communities, plant and fauna species. However, Annexure 1 of the proposed Biodiversity Decree Law provides an "Interim list of protected species" in Timor-Leste including birds, mammals, amphibians, reptiles and plants, and Annexure 2 is an interim list of "Prohibited Invasive Alien Species" (see www.laohamutuk.org/Agri/EnvLaw/div/SpeciesLists.pdf). This is not yet law but provides an indicative list of flora and fauna species considered important by the Timor-Leste Government, and flora and fauna species which have the potential to harm biodiversity.

The Status of Timor-Leste Flora and Vegetation

The flora of Timor is poorly known, but a review of available data was given by Cowie (2006) with at least c. 1,488 plant species listed for Timor (I. Cowie *pers. comm*.). The flora is transitional between those of the tropical rainforests of Sundaland and the Australo-Papuan region (Roos *et al.* 2004). A large proportion of the dry tropical forest plants of Timor occur also in northern Australia, and often more widely in Malesia (Cowie 2006). A small number of Timor or Lesser Sunda endemic plants are from predominantly Australian families or genera (e.g. *Diuris freya* [Orchidaceae], *Eucalyptus urophylla*, *E. alba, E. orophila* [Myrtaceae], and *Casuarina junghuhniana timorensis* [Casuarinaceae]) (Monk *et al.* 1997; Cowie 2006).

Consideration of vegetation types, structure and floristic composition on Timor has been given by:

- Meijer Drees (1951) "*Distribution, Ecology and Silvicultural Possibilities of the Trees and Shrubs from the Savanna-Forest Region in Eastern Sumbawa and Timor (Lesser Sunda Islands)*" which describes vegetation types and their floristic components, particularly in open woodlands-savannas;
- Martin and Cossalter (1977): "*The Eucalyptuses of the Sunda Isles*" describes the status, taxonomy, distribution, floristic composition of *Eucalyptus* woodlands on Timor and the Lesser Sundas islands.
- Metzner (1977): "*Man and environment in Eastern Timor: a geoecological analysis of the Baucau-Viqueque area as a possible basis for regional planning"* which describes plant species composition, vegetation structure and maps vegetation types in the Baucau region including the study area;
- Monk *et al*. (1997) "*The Ecology of Nusa Tenggara and Maluku*" provides a vegetation classification based on literature review, and plant species composition and structure of vegetation types.
- Whistler (2001) "*Ecological Survey and preliminary botanical inventory of the Tutuala beach and Jaco Island*" described the vegetation types, structure and composition in the far east of Timor-Leste.
- Cowie (2006) "*Assessment of floristic values of the proposed Jaco-Tutuala-Lore National Park, Timor-Leste (East Timor)"* The most detailed consideration of vegetation communities in Timor-Leste, but focusing mostly on Closed tropical forest types.
- Grantham *et al.* (2011) "*Timor-Leste: interim national ecological gap assessment*". An attempt at an environmental classification using "geoformations" based on a geological classification map, a Land use classification (mixed in with elevation and other environmental data) from the ALGIS Unit (Ministry of Agriculture and Fisheries), in the absence of a detailed information on the distribution of vegetation communities. This was part of a conservation activity to conserve "representative examples of geophysical settings".
- WorleyParsons (2012) "*Suai supply base Environmental Impact Assessment, attachments: Flora and Fauna Final Technical report*" describes vegetation types, and provides a botanical inventory of the Suai supply base area on the south coast of Timor-Leste.

The dominant natural vegetation types are broadly savanna woodlands (often dominated by *Eucalyptus*, *Acacia*, *Borassus* and *Corypha*), open forest, Closed canopy tropical forest ("monsoon forest", "rainforest"; from high rainfall evergreen forest to drier types, typically driven by interactions of elevation-rainfall-geology and topography). Closed Tropical Forest is biologically rich with diverse tree and shrub communities. It also provides habitat for rich communities of endemic bird, mammal, and reptile communities. Historically much Closed Tropical Forest on Timor has been converted to agriculture, harvested during colonial times, or converted during Indonesian administration to reduce safe havens for resistance fighters.

In Timor-Leste loss or conversion of Closed tropical forest is the major driver of population loss and decline of biologically significant tropical forest and species listed by the IUCN as threatened with extinction. This includes at least three tree species, a species of shrew, the Vulnerable Western Naked-backed Bat *Dobsonia peronii*, one Critically endangered bird (Yellow-crested Cockatoo *Cacatua sulphurea*) three Endangered birds (Timor Green Pigeon *Treron psittaceus*, Wetar Ground Dove *Gallicolumba hoetdi* and Timor Imperial Pigeon *Ducula cineracea*) and an additional 13 Near threatened bird species. Loss or conversion of tropical forest is the most important driver of population decline of most of these species, but hunting and or trade has been important driver of population decline for several species such as the Yellow-crested Cockatoo and pigeons. Recent invasions are also driving declines: the Black-spined Toad *Bufo melanostictus* has been implicated in the decline of some native snakes and amphibians, but remains very poorly known.

The *Eucalyptus* woodlands have typically been given little conservation attention in Timor-Leste, as they have been assumed to be less biologically significant than Closed Tropical Forests. In terms of tree and plant richness, bird and bat richness this clearly is the case. *Eucalyptus alba* was originally described as a species from specimens collected on Timor, and under present-day taxonomy occurs widely in northern Australia, as well as Flores, Alor, Wetar and other islands in the Lesser Sundas. Martin and Cossalter (1977) state that "*E. alba* does not pose any problem of botanical nomenclature; the species present in the Sunda Isles is exactly the same as the one found in the north of Australia". However, *E. alba* on Timor and neighboring islands is clearly a different species to the tree present in northern Australia (I. Cowie pers. comm. 2010), and may consist of several endemic islands forms. Quite extreme morphological variation in *E. alba* is described for the Timor-Leste region by Martin and Cossalter (1977), and further research might recognize taxa within Timor.

The Status of Timor-Leste's Fauna

Timor has a classical island fauna characterized by low overall species richness and high levels of endemism. A feature of Timor is the high proportion of wildlife that are strongly associated with tropical forest. Timor's present-day fauna is the result of natural colonization by overwater dispersal and more recent human-mediated introductions (from the Orient, Australo-Papuan, Wallacea and Old World, with some tramp ants from Africa and South America), subsequent in-situ speciation and extinctions over the last 4 My.

Historical collecting and observation of Timor's birds was summarised in a major monograph *The Birds of Wallacea* (White and Bruce 1986) with 212 birds listed. Subsequent field observations including species status and habitat use have been summarized in a field guide (Trainor *et al.* 2007a). Endemism is high. There are 126 resident landbirds (excluding migrants/visiting birds and waterbirds). On current information there is at least seven species endemic to Timor Island, at least 39 species (31% of resident landbirds) are globally restricted-range (with distributions of less than 50,000km^2) and 44 species (35%) are endemic to the Wallacean region (CRT unpubl. data). About 80 birds are considered forest specialists and these species particularly susceptible to forest loss and conversion.

At least 52 mammal species are known from Timor, but remarkably, other than bats few native land mammal species have been recorded since 1800 – the Thin Shrew *Crocidura tenuis* and

Timor Rat *Rattus timoriensis* and undescribed shrews. The Long-tailed Macaque (*Macaca fascicularis*) has long been considered as an introduced species, but recent molecular work shows that it has existed on Timor for c. 930,000 years (range 740,000-1,240,000 years: Liedigk *et al.* 2015). Bats are the most speciose group, with at least 28 species accepted for Timor-Leste, and possibly as many as 35+ taxa present (Armstrong & Konishi 2015). A single monograph covers the bats of Timor (Goodwin 1979) but a series of surveys by the Western Australian Museum (Kitchener *et al*. 1992, 1995), and more recently (Helgen 2004; Armstrong 2006) has added new island records and clarified the taxonomic status of some species including endemic and undescribed taxa. Greater effort of trapping and collecting specimens, and recording of bat calls while releasing live bats is needed to advance knowledge of bats in Timor-Leste. At least 17 mammals have been introduced to Timor (Glover 1986).

Knowledge of the taxonomic status amphibian and reptile faunas has improved greatly over the past 10 years. Of c.55 species listed in 2015 (excluding marine species/turtles), approximately 26 species may be undescribed (O'Shea *et al*. 2015). This includes at least two amphibians, eight geckos, 14 lizards and two snake species (O'Shea *et al*. 2015). The habitat use, distribution and status of most amphibian and reptiles species remains very poorly known. Current knowledge suggests that many species may be highly localized on Timor (O'Shea *et al*. 2015) but this may also be caused by low survey effort. Habitat use patterns are also poorly known making conservation assessments, and assessments of environmental impact, somewhat problematic.

Conservation planning and policies in Timor-Leste

The history of protected area establishment in Timor-Leste is brief. In 1967 two forest reserves were established by the Portuguese colonial government at Tilomar (Suai district) and Lore (Lospalos), with the aim of protecting Sandalwood *Santalum album* (FAO/UNDP 1982). In 1982, nine West Timor and eight East Timor sites, including Tilomar and Lore, were identified as key representative natural areas as part of the Indonesian-wide *National Conservation Plan* (FAO/UNDP 1982). In 2000, the UNTAET administration prepared interim legislation 'protecting designated areas, endangered species, coral reefs, wetlands, mangroves areas, historic, cultural and artistic sites, conservation of biodiversity and protection of biological resources of Timor-Leste' by designating 15 'Protected Wild Areas' (*Regulation NO. 2000/19 On Protected Places* (UNTAET 2000). The 15 sites included all of those proposed by the FAO/UNDP in 1982 covering at least 1,868 km^2, or about 13% of the nation's land area but boundaries were not defined and the 15 sites have not been recognized in land use planning (Trainor *et al.* 2007b). In collaboration with the Timor-Leste government, BirdLife International conducted field surveys, which were published as an Important Bird Areas directory for Timor-Leste, including 16 site accounts (Trainor *et al.* 2007b). This included many sites previously gazetted under the United Nation's interim legislation. In August 2007 the nation's first protected area - Nino Konis Santana National Park - was declared, and since then many additional sites have been identified as conservation areas.

Timor-Leste became a party to the Convention on Biological Diversity in 2007, the UN Convention to Combat Desertification, and the UN Framework Convention on Combating

Climate Change. The Biodiversity Decree Law 2012 is a means to fulfilling Timor-Leste's obligation under the Convention on Biological Diversity to provide the legal framework for "conserving biodiversity, sustainably using biological resources and equitably sharing benefits generated from genetic resources". More specifically:

> *The State shall define and implement a strategy to ensure conservation of biodiversity: a. The protection and conservation in situ and ex situ populations of species and their habitats, and ecosystems; b. Reproduction in quality and quantity of the species, especially threatened and endangered species; c. The rehabilitation and restoration of degraded habitats and ecosystems and recovery of threatened or endangered species; d. The creation and maintenance of a national system of protected areas ensure the ecological coherence of the territory and the continuity of species and ecosystems; e. Access and equitable sharing of benefits arising from sustainable use of genetic resources and traditional knowledge.*

Some of the most relevant guiding principles relating to environmental assessments in the draft Base Law on Environment:

- *Preventive principle: Programs, plans or projects with environmental impact must anticipate, prevent, reduce or eliminate the primary causes and correct the effects which may alter the quality of the environment.*
- *Precautionary principle: the lack of full scientific certainty of the existence of a risk of serious or irreversible damage to the environment should not be used as a reason for postponing the adoption of effective measures to prevent or minimize the change in quality.*

Environmental Licensing Decree Law No. 5/2011

The main guiding principles of the regulation of the Environment Licensing Decree Law are:

- *Ensuring the participation of the community and of the public in the Environmental Assessment process.*
- *Identifying and assessing the consequences of the development proposals for the environment;*
- *Creating the conditions for minimizing or eliminating the environment and social negative impacts arising from the implementation of projects;*
- *Determining the environmental and social protection measures to be applied at the time the projects are implemented;*
- *Instituting a process for issuing environmental licenses resulting from environmental assessment that can truly contribute to environmental control.*
- *Overseeing and monitoring the projects according to the provisions of the Environmental Management Plan (PGA).*

This report:

- *Identifies vegetation communities, describes the structure, plant composition and broad environmental relationships of vegetation communities at the study sites*
- *Identifies plant species of conservation concern (ie IUCN listed species), describes their location and habitat affinities.*
- *Describes the terrestrial fauna of the study sites – including abundance, composition, habitat relationships and conservation status.*
- *Makes recommendations to minimize environmental harm caused by the proposed mine.*

Methods

Local participation by Timor-Leste workers

During the field survey of flora, vegetation and fauna four local hamlet chiefs (Cefe aldeia) worked in the field with consultants at Mine-I-1, Jetty and Plant, and two local villagers worked with consultants at the Clay site (Figure 1).

Figure 1. Local assistants Cypriano Belo and Pedro da Costa search for fauna species under rocks, rockwalls and logs during the survey.

Flora and Vegetation survey

A representative assessment of the dominant plant types and their abundance and associations was undertaken throughout the key development zones, Plant Site (1km^2), Mine I-I, hereafter “Mine” (5.76km^2; see Figure 2), Clay Mine (4.0km^2) and Jetty (0.05km^2) during 20-25 May 2015. The assessment methodology included a combination of initial random points within the key test sites that were then further expanded to include any different neighboring vegetation assemblages based on field observations.

Each survey site consisted of individual 25m x 25m ($625m^2$) quadrat sampling zones. Within each of these zones, the dominant vegetation types were assessed and sampled at the upper, middle and lower stratums. Additional information recorded at each site included disturbance, basal area(m^2), height range (m), weed cover abundance, canopy cover (%), litter cover (%), gravel extent (%), bare earth (%) and soil types. At a floristic level, any unusual plant specimens that could not be identified in the field were also collected for identification later. In total 22 different sites were sampled over $13,750m^2$. Individual site survey reports are provided as Appendix 1, and a full list of plant species is given as Appendix 2. Vegetation quadrat sample locations and tracks are shown graphically in Figures 3 & 4.

Vegetation assemblages in this report are described in terms of "structural formation" in accordance with the widely accepted Australian National Information System (NVIS) standards (ESCAVI) Department of the Environment and Heritage, 2003) at Level II. The vegetation community definitions used in NVIS fit well with many of the woodland and Closed Tropical Forest environments of Timor-Leste and both countries share many similar species. In compiling this report attention was also given to previous recognized works in classifying vegetation in Timor-Leste including: Cowie (2006); Meijer Drees (1951) and Monk *et al*. (1997).

Figure 2. View of Mine site and Plant site looking North West.

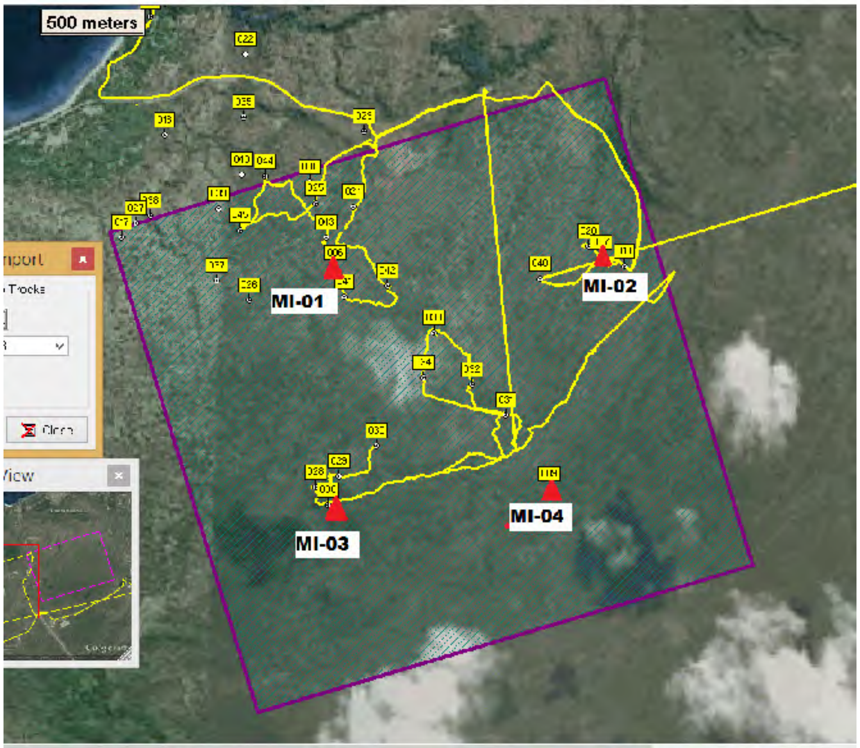

Figure 3. Vegetation quadrat survey and GPS tracks on the Mine site, Plant and Jetty.

Figure 4. Vegetation quadrat survey and GPS tracks on the Clay site.

Fauna survey

Bird Survey

A total of 25 Point counts were carried out through each of the study areas, mostly in the morning when birds are most actively vocalizing. All birds seen or heard within a 50 m radius of the sample center point would be recorded on a proforma, and birds recorded beyond approximately 50 m would be noted separately. At the same time 10 minute searches for reptiles, amphibians and mammals were conducted by either one or two local assistants.

Acoustic Bat Recording

Recording units convert ultrasonic echolocation signals produced by bats into audible electronic signals, which are later analysed for species specific calls. Four recording units were set up in the main habitats in several sites particularly targeting significant bat habitat such as Closed Tropical Forest, caves and cliffs. Units were left in place for 2-5 night nights at Site I-1 and Clay site for a total of 26 recording unit x night sessions. There was a technical issue with the compatibility of microphones and recording devices in the May survey. After these were resolved an additional 2-day repeat survey in late June was done to ensure a substantial set of data was collected (Table 1). Bat calls were analysed and assigned to species or call types by Specialised Zoological (see Armstrong & Konishi 2015).

Opportunistic Searches

Opportunistic searches were carried out to target specific habitats (e.g. cliffs, caves, rock outcrops, Closed Tropical Forest) potentially supporting fauna of conservation significance. Active searching involved raking through leaf litter, overturning rocks and logs, and investigating overhangs.

- Birds – opportunistic records of all bird species (and other fauna) were written in a notebook, together with coordinates, habitat and elevation data.
- *Nocturnal Spotlighting* - Spotlighting and head torching at night on foot is an important surveyed nocturnal fauna, such as snakes, geckos, owls and nightjars. Spotlighting was done at the Mine and Clay sites for one night over 2 hrs each.
- *Targeted but opportunistic bat searches: caves, escarpment and overhangs.* Coastal palms were also searched for palm tree roosting species.

Fauna Habitat assessment

Fauna habitat was characterized by filling in a proforma including coordinates, elevation, major vegetation structural features such as estimates within a 50 m radius of a central point for percentage canopy cover and canopy height, and percentage cover of various vegetation layers, rock and litter cover, number of logs and estimates on a one to five scale of relative disturbance level (fire, livestock grazing, agriculture and weeds).

A fauna species list by site is included as Appendix 4 and fauna for each of the 25 point counts included as Appendix 5; individual fauna habitat proformas are included as Appendix 6, and a summary of coordinates, habitat and elevation for each of the 25 point counts included as Appendix 7. A summary of acoustic bat recordings are given as Appendix 8, and a report on analysis and identification of bat recordings is given as Appendix 9 (Armstrong & Konishi 2015).

Results

Vegetation and Flora

JETTY SITE

The Jetty is located at the nearby beach and will include a conveyor belt to the plant site. The area is flat and already highly modified by temporary dwellings, grazing and some agriculture. The general environment is characterised by sandy soils and established breadfruit *Artocarpus altilis* and *Corypha sp* palm groves. The area is also severely infested with weeds (Figure 6).

The overall site is dominated by a relatively uniform coastal Closed Tropical Forest (70%) which is most likely a combination of existing forest and mature plantation trees. The remaining area (30%) is cleared grazing land and residential farms.

Figure 6: Jetty site

Vegetation type, abundance and height range

The coastal Closed Tropical Forest is dominated by *Borassus flabelifer, Corypha utan* and *Artocarpus integer*. Additional examples of *Artocarpus atilis, Cocos nucifera, Persea americana* and *Tamarindus indica* were recorded for the upper stratum. The height range within the

Closed Tropical Forest systems is 20 to 30m. The middle stratum was largely absent but included some juvenile representatives of the upper stratum. The lower stratum is primarily dominated by a heavy infestation of the weed *Lantana camara* with other areas characterised by high leaf litter from the overhead palms.

Qualitative description

Overall, the Jetty site is a heavily modified plantation environment with a severe infestation of *Lantana camara* throughout. The biological diversity at these sites was very low and overall the site was not representative of a pristine coastal/beach forest. No plant species listed by the International Union for Conservation of Nature (IUCN) were found at the Jetty site.

PLANT SITE

The plant site is located on NNE facing slopes and plains relatively close to the beach, road and proposed jetty area. The site is characterized by shallow limestone soils with scattered limestone rock outcrops, minor ridges and gullies sloping towards the beach. The site consists predominantly of very open savannah woodland (95%) which has been extensively modified for agriculture and grazing in places. The remaining areas were isolated patches of Closed Tropical Forest systems (5%), occurring in depressions and drainage floors and often surrounded by introduced *Lantana camara* (Figures 7 & 8). For representative purposes surveys were conducted in each of these two systems.

Vegetation type, abundance and height range

The open woodland environment at the plant site is dominated by *Eucalyptus alba* and Ceylon Oak *Schleichera oleosa* (Tetum: Aidak) ranging in height from 8 to 10 m. Canopy cover in this area was very sparse at less than 10%. Native species present in the middle stratum included, *Eucalyptus alba* juveniles, *Canarium vulgare* (Tetum: Kai Tudo) and *Annona squamosa* (Tetum: Ai Ata) but both the middle and lower stratums are primarily dominated by introduced invasive species, including, *Ziziphus mauritiana* (Chinee Apple), *Lantana camara* and *Chromolaena odorata* (Siam Weed). Some grassland is intact with the dominant grass being *Iseilma minutiflorum*. The Closed Tropical Forest environment is dominated by *Ficus* species (unidentified) ranging in height from 10 to 15 m and the invasive *Tecoma stans* (Tetum: Ai funan kinur) as a secondary dominant small tree. The Closed Tropical Forest site had a dense canopy of approximately 70%. Additional native trees recorded at this site include, *Intsia bijuga* (Borneo Teak), *Tamarindus indica*, *Senna timoriensis* and *Streblus asper.* The middle stratum was dominated by juvenile representation of the upper storey with 70% coverage of leaf litter.

Qualitative description

The open woodland site had an 80% level of disturbance from weed infestations and grazing. The Closed Tropical Forest area had a 30% level of disturbance from weeds on its edges but was relatively weed free and undisturbed at its centre. The dominant weeds across the two sites include, *Tecoma stans*, *Lantana camara*, *Jatropha gossypifolia*, *Chromolaena odorata* and *Hyptis suaveolens. Intsia bijuga* (Borneo Teak) was present at survey site P002 (Figure 9) and is listed as Vulnerable by the International Union for Conservation of Nature (IUCN) Red List.

Figures 7 & 8: Mr Carlos Assis Bento sampling vegetation at P002 Plant site

Figure 9. Intsia bijuga was recorded on the Plant site at P002.

MINE SITE

The mine site is located across NE to NW facing stepped slopes and plains on limestone outcrops with higher slopes on the southern edge of the site and flatter plains towards the northern boundary. The site is predominantly uniform woodland to open woodland (95%) with isolated small patches of Closed Tropical Forest (5%) occurring in minor ravines and gullies, and grassland. The site is characterized by shallow limestone soils and extensive scattered, small to medium sized limestone rock outcrops. Nine separate survey locations were undertaken. These sites radiated out from the test drill locations and targeted different vegetation assemblages wherever available.

Vegetation type, abundance and height range

The open woodland environment (95%) at the mine site is dominated by relatively uniform *Eucalyptus alba* and *Schleichera oleosa* assemblages, ranging in height from 8 to 10m (Figure 10). Additional native species occurring in lesser numbers in the upper stratum included, *Acacia sp, Alstonia actinophylla, Gmelina arborea, Dalbergia timoriensis, Miliusa sp, Santalum album, Senna timoriensis and Syzigium nervosum.* The middle stratum is largely absent but includes examples of dominant juveniles and various invasive weeds including, *Ziziphus mauritiana*, *Lantana camara* and *Chromolaena odorata* (Siam Weed). The lower stratum is grassland, predominantly *Iseilma minutiflorum*, with mixed herbs including *Indigofera linifolia* and *Uraria lagopodiodes*.

The Closed Tropical Forest (5%) patches are characterised by canopy cover in excess of 70% and are typically dominated by mature *Schleichera oleosa* but also included lesser examples of *Acacia sp, Cryptocarya foetida, Dalbergia timoriensis, Syzigium nervosum* and *Santalum album*. The height range within the Closed Tropical Forest systems is 8 to 10m. The middle stratum within these isolated Closed Tropical Forest systems exhibited the greatest species richness of all sites surveyed and included examples of *Dichapetalum timorense, Dischidia major, Neoalsomitra podagrica, Tricolor Lindle, var insignis* and *Wrightia pubescens.* The lower stratum within the Closed Tropical Forest patches is characterised by higher than average leaf litter and mixed herbs and grasses including, *Breynia cernua, Imperata cylindrical, Iseilma minutiflorum*, *Justicia procumbens, Phyllanthus virgatus*, and *Uraria lagopodiodes.*

Qualitative description

The mine site open woodland (95%) varies in the degree of disturbance and degradation dependent on physical barriers such as excessive exposed limestone outcrops, which appears to restrict grazing animal access somewhat. However, across the majority of open woodland sites weed species, including *Hyptis sauvleons, Chromolaena odorata, Jatropha gossypifolia, Lantana camara, Tecoma stans* and *Ziziphus mauritiana* were usually secondary dominant species in each of the stratum. The percentage of weed infestation varied from 3% to 45% across the surveyed locations. On average the canopy cover in the open woodland environments is approximately 10%.

Santalum album was present at survey site MI03-001 and is listed as Vulnerable on the International Union for Conservation of Nature (IUCN) Red List. *Indigofera linifolia* was also identified at MI02-001 and is listed as Least Concern.

Figure 10: Representative open woodland site.

CLAY MINE SITE

The clay mine site is located in the Wailacama village area and is characterised by greater topographic relief than the other project locations with steep slopes ranging in aspect from E to WNW, incised rivers and heavy grey clay soils. The overall site is dominated by Closed Tropical Forest (60%; Figure 11) and degraded woodland (40%). However, vegetation communities within the survey localities of the 4 test pit sites included, Closed Tropical Forest (30%), bamboo forest (20%) and degraded open woodland (50%). These survey sites radiated out from the test drill locations and targeted different vegetation assemblages wherever available.

Vegetation type, abundance and height range

The Closed Tropical Forest (30%) patches are characterised by canopy cover in excess of 70% and are primarily dominated by *Peltophorum pterocarpum* but also included lesser examples of *Hibiscus hirtus*, *Terminalia cattapa, Ziziphus oenopolia* and *Ziziphus timoriensis.* The height range within the Closed Tropical Forest systems is 10 to 15m. The middle stratum within the Closed Tropical Forest systems exhibited only moderate diversity with the majority of the stratum taken up by juvenile representatives of the upper stratum. Lesser examples found include, *Citrus sp, poss gracilis*, *Pometia pinnata, Schleichera oleosa* and *Miliusa sp.* The lower stratum within the Closed Tropical Forest patches is characterised by high leaf litter. Both Closed Tropical Forest survey sites were heavily infested with *Lantana camara* and lesser amounts of *Jatropha gossypifolia* and *Chromolaena odorata.*

Figure 11: Closed Tropical Forest example at TP01-001 Clay Mine

The bamboo forest environments (20%) were concentrated in the south of the project area and were usually concentrated in isolated patches with only limited diversity through the middle and lower stratums. The dominant bamboo species present across both sites is a thorny clumping style *Dendrocalamus sp* with a canopy cover between 30 to 45% and a height range from 10 to 15m. Lesser examples of *Acacia leucophloea*, *Peltophorum pterocarpum*, *Pterocarpus indica*, *Senna surattensis* and *Sesbania grandiflora* and *Tectona grandis* are also present. The middle stratum is limited and included examples of small *Acacia nilotica* and *Senna surattensis.* The lower stratum in the bamboo forest systems (Figure 12 & 13) exhibits a higher degree of diversity and included examples of *Ageratina riparia, Brucea javanica, Canavalia papuana*, *Desmodium gangeticum* and *Gliricidia sepum.* Both bamboo survey sites have high levels of *Chromolaena odorata and Acacia nilotica (juvenile)* infestations.

The open woodland environment (50%) across the clay mine site is characteristically located on hills and slopes between sections of Closed Tropical Forest and located largely on the eastern side of the site between Test Pits 01 and 04. The majority of these sites were heavily degraded, particularly through grazing and weed infestations. Of the five survey sites undertaken two had extremely low biological diversity. Canopy cover at these sites was less than 10% with a tree height range from 8 to 15m. In the upper stratum, *Acacia leucophloea* and *Peltophorum pterocarpum* were the dominant species, with lesser examples of *Pterocarpus indicus* (Figure 14) and *Eucalyptus alba.*

Figures 12 & 13: Bamboo Closed Tropical Forest at TP04-001 (Dendrocalamus sp. & Ceiba petandra)

The middle stratum is largely absent or dominated by well-established invasive species including *Acacia nilotica*, *Lantana camara* and *Ziziphus mauritiana.* The lower stratum ranged from exposed soils with scattered limestone outcrops to a relatively diverse grassland of *Iseilma minutiflorum*, with mixed herbs including *Indigofera linifolia* and *Thecanthes concreta*. Most lower-stratum sample sites also included *Acacia nilotica*, *Hyptis sauvleons, Lantana camara* and *Chromolaena odorata.*

Qualitative description

Overall, the clay mine site has a mixture of either Closed Tropical Forest or bamboo forest on the steeper slopes and heavily degraded open woodlands on the hills and rises between. The Closed Tropical Forest environments exhibit a higher than average biological diversity, whereas the open woodland sites had very low biological diversity. Across the majority of open woodland sites weed species, including *Hyptis sauvleons, Chromolaena odorata, Jatropha gossypifolia, Lantana camara,* and *Ziziphus mauritiana* were usually secondary dominant species in each of the stratum. The percentage of weed infestation varied from 10% to 100% across the surveyed locations.

Pterocarpus indicus was identified at survey site TP01-002 and is listed as Vulnerable on the International Union for Conservation of Nature (IUCN Red List: Figure 14). *Indigofera linifolia* was present at survey site TP03-001 and is listed as Least Concern.

Figures 14: Mr Carlos Assis Bento with a Rosewood Pterocarpus indicus tree.

Fauna survey

A total of 87 vertebrate fauna species were recorded during the survey including two amphibians (one native taxon), eight reptiles (six native taxa), 21 mammals (12 native taxa, 9 introduced species) and 56 bird species (Table 2). Three landsnail taxa were also recorded. The fauna was highly typical of lowland woodland habitats on Timor in particular, with some forest specialized birds present, particularly associated with the Clay mine.

A large proportion of the recorded fauna, especially among amphibians, reptiles and mammals consisted of introduced/tramp or invasive species which are not native to Timor-Leste. Some introduced species were common e.g. Black-spined Toad (*Bufo melanostictus*), Tokay Gecko (*Gekko gecko*), with livestock species such as Water Buffalo, Banteng/cattle, horse and sheep regularly observed grazing at the Mine and Clay sites. All 12 bat species recorded were native species.

The greatest number of species was recorded in the largest study sites with 57 fauna species recorded at the Mine I-1 and 72 fauna species recorded in the Clay site, with fewer species at the Jetty and Plant. Only two individual native frogs were recorded, but the invasive Black-spined Toad was frequent in the Mine and Clay areas. At least 10 echolocating bat species were present in the project area, with four species able to be identified to species-level. At least four species of cave roosting bat were recorded and identified to species-level (two species of *Rhinolophus; Hipposideros diadema*, *Miniopterus australis*), with several others likely (other *Miniopterus* spp.; *Taphozous* spp.) to occur (Appendix 9: Armstrong & Konichi 2015). Thus, up to a maximum of eight out of ten echolocating bat species recorded on the survey use caves for daytime roosting (Armstrong & Konichi 2015). The Indonesian Short-nosed Fruit Bat was the only native mammal directly recorded with small numbers observed under palm fronds at the Jetty site. Local assistants reported that the Long-tailed Macaque was present at the Plant, Mine I-1 and Clay Site.

Table 2. Fauna species richness at study sites. The number of introduced or livestock species is shown in parentheses. In addition three landsnail taxa were recorded at Plant and Mine I-1, and two landsnail taxa were recorded at the Clay mine.

	Amphibians	Reptiles	Mammals	Birds	Total
Jetty	0	4(2)	11(1)	8	23
Plant	0	2(2)	4(3)	14	20
Mine I-1	1(1)	3(2)	14(8)	39	57
Clay mine	2(1)	4(2)	18(8)	48	72

Of the 56 bird species recorded, 22 were globally restricted-range species, six species were IUCN Near threatened species (all of these were also restricted-range species) and 23 species are considered as “forest specialists”. The Clay Site had the greatest number of restricted-range species (all 22 species recorded during the survey), Near threatened (all six species) and forest specialist bird species (all 23 species), but the more open habitats of the Jetty, Plant and Mine hosted fewer bird species of conservation concern and were dominated by woodland-open country (non-forest specialist) bird species. Four open-country bird species were absent from the Clay mine (Appendix 4). Patterns of bird species distribution closely follow vegetation patterns, with Near threatened, restricted-range and forest specialized birds strongly associated with Closed Tropical Forest which was unsampled or absent at the Jetty, Plant and Mine site.

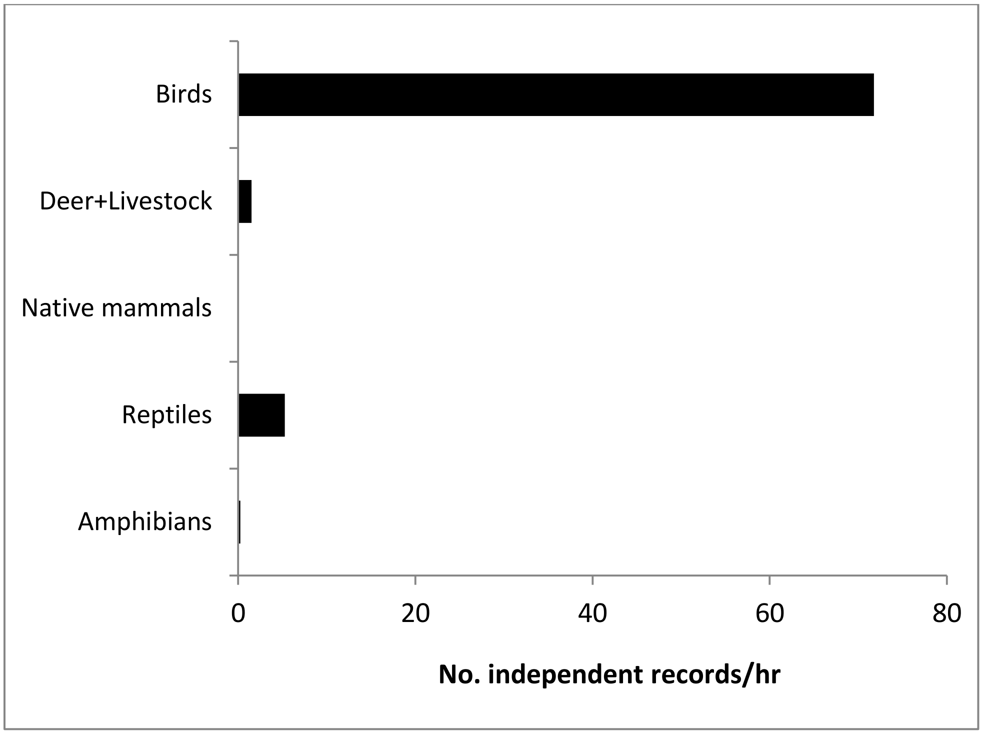

Figure 15. Relative abundance: the mean number (per hr) of independent fauna species records at systematic point counts (from total of 250 mins). Note: acoustic bat recording was not done at point counts.

There was a total of 315 independent fauna records at the 24 point counts (species x point counts) dominated by 287 (91.1%) bird records (Figure 15). There was a single point count record of an amphibian (Black-spined Toad), 21 records of reptiles mostly of Tokay Gecko and House Gecko, and just six point count records of mammals (all livestock or Timor Deer *Cervus timorensis*).

Ten bird species were recorded frequently at nine or more of the 24 point counts (Figure 16): Barred Dove *Geopelia maugeus* (19), Streak-breasted Honeyeater *Meliphaga reticulata* (18), Blue-cheeked Flowerpecker *Dicaeum maugei* (18), Fawn-breasted Whistler *Pachycephala orpheus* (15), Plain Gerygone *Gerygone inornata* (15), White-bellied Bush Chat *Saxicola gutturalis* (14), Timor Friarbird *Philemon inornatus* (13), Zebra Finch *Taeniopygia guttata* (12), Northern Fantail *Rhipidura rufiventris* (11), Timor Figbird *Sphecotheres viridis* (10), Rainbow Bee-eater *Merops ornatus* (10) and Glossy Swiftlet *Collocalia esculenta* (9).

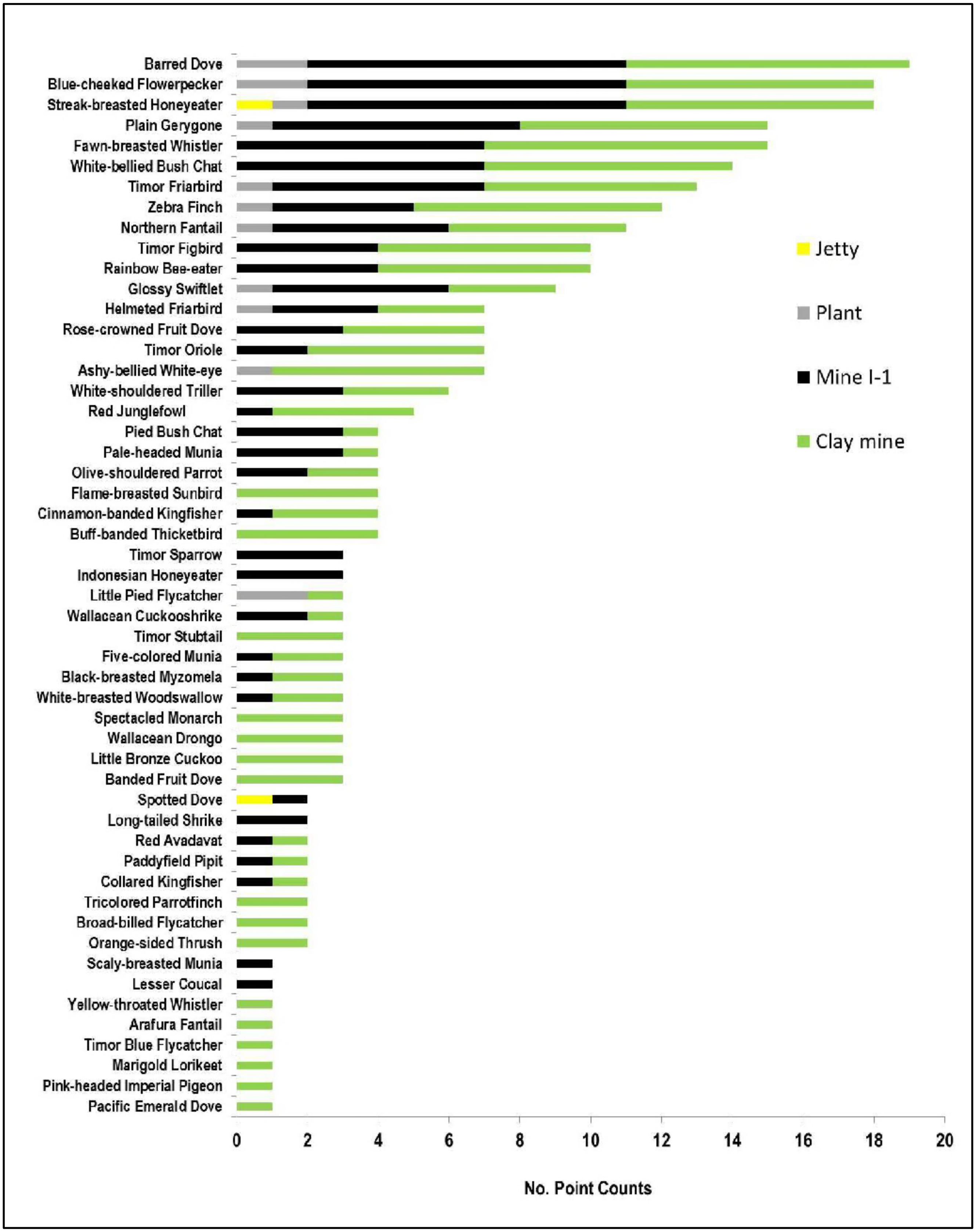

Figure 16. Frequency of occurrence of bird species in 24 point counts at the Jetty, Plant, Mine I-1 and Clay mine.

JETTY SITE

Fauna habitat description

The Jetty site consisted of degraded Beach Forest to 19 m tall with 30-70% canopy cover, dominated by *Corypha* palm, Coconut palm *Cocos nucifera* and breadfruit *Artocarpus* sp, with weedy or bare understorey. There were some logs on ground and patchily extensive leaf litter.

Fauna composition and significance

Nine of the 10 insectivorous microbat species were present. Approximately 30 Indonesian Short-nosed Fruit Bat (*Cynopterus titthaecheilus*) were photographed roosting under *Corypha* palm fronds at the Jetty and the Timor Inornate Bronzeback (*Dendrelaphis inornatus*) snake was observed in litter at the site. Otherwise few bird species were recorded, and it was characterized as having low to moderate fauna habitat quality because of extensive disturbance to natural vegetation.

The following photographs illustrate habitats (Figures 17-28), amphibians, reptiles, mammals and birds in habitat at Baucau sites (Figures 29-46) and landsnail taxa collected (Figures 47-48).

Figure 17. Main habitat types at study sites: Corypha palm dominated Beach forest at Jetty.

Figure 18. Main habitat types at study sites: Eucalyptus alba woodland view across Mine and Plant sites

Figure 19. Typical Eucalyptus alba woodland with a grassy understorey on Mine.

Figure 20. Main habitat types at study sites: Schleichera oleosa dominated woodland with weedy understorey on Mine.

Figure 21. Main habitat types at study sites: well developed Closed Tropical Forest at Clay site.

Figure 22. Old rock wall (red arrow) showing c.50-100+ year old small-holder agricultural boundary in present-day well-developed Closed Tropical Forest at Clay site.

Figure 23. Old rock wall showing c.50-100+ year old small-holder agricultural boundary on Mine site in present day woodland dominated by Scheichera oleosa.

Figure 24. Main habitat types at study sites: bamboo dominated Closed Tropical Forest at Clay site.

Figure 25. Main habitat types at study sites: Irrigated ricefield at Clay site with Closed Tropical Forest background.

Figure 26. Main habitat types at study sites: Heavily grazed shrubland on eroded clay slopes fringed by Closed Tropical Forest at Clay site.

Figure 27. Specific fauna habitat features: Tree hollow in Eucalyptus alba tree at Mine.

Figure 28. Specific fauna habitat features. Bedded limestock rock substrate with few surface-free rocks at Plant site.

Figure 29. Specific fauna habitat features. Hollow tree stem with Tokay Gecko at Plant.

Figure 30. Specific fauna habitat features: Numerous landsnails Parachloritis c.f. newtoni (possibly baucauensis) sheltering under log at Mine.

Figure 31. Indonesian Short-nosed Fruit Bat (Cynopterus titthaecheilus) under Corypha palm frond at Jetty.

Figure 32. A free-range Water Buffalo at wallow on Mine site.

Figure 33. Several horses were seen grazing at the Mine site.

Figure 34. Flocks of sheep were seen grazing at the Mine and Plant sites always accompanied by a shepherd.

Figure 35. Undescribed Rice Paddy Frog (Fejervarya sp 1) at Mine site – the only native amphibian recorded during the survey.

Figure 36. A Black-spined Toad (Duttaphrynus melanostictus) at Mine. This recently arrived alien/introduced and toxic toad was particularly common at the Clay Mine site.

Figure 37. A single White-lipped Island Viper (Trimeresurus insularis) was observed during at the Mine.

Figure 38. The widespread House Gecko (Hemidactylus frenatus) is a vocal species that was commonly recorded at Mine and Plant sites. The photo shows an unusual dark morph individual.

Figure 39. The vocal Tokay Gecko (Gekko gecko) was common at the Clay site and Plant site.

Figure 40. Carlia sp 'lowland' c.f Kaiser et al. (2011), at Mine.

Figure 41. Carlia skink 'Baucau' at mine.

Figure 42. The Near threatened Olive-shouldered Parrot (Aprosmictus jonquillaceus) was recorded regularly at the Mine.

Figure 43. The only grassland specialist recorded during the survey: Paddyfield Pipit (Anthus rufulus) was common at the Clay site.

Figure 44. The Near threatened Orange-sided Thrush (Geokichla peronii) is a forest specialist bird, this juvenile bird was photographed in bamboo at Clay site.

Figure 45. The Near Timor-endemic White-bellied Chat (Saxicola gutturalis) at Mine.

Figure 46. The Near threatened and near Timor-endemic Timor Sparrow (Lonchura fuscata) at Mine.

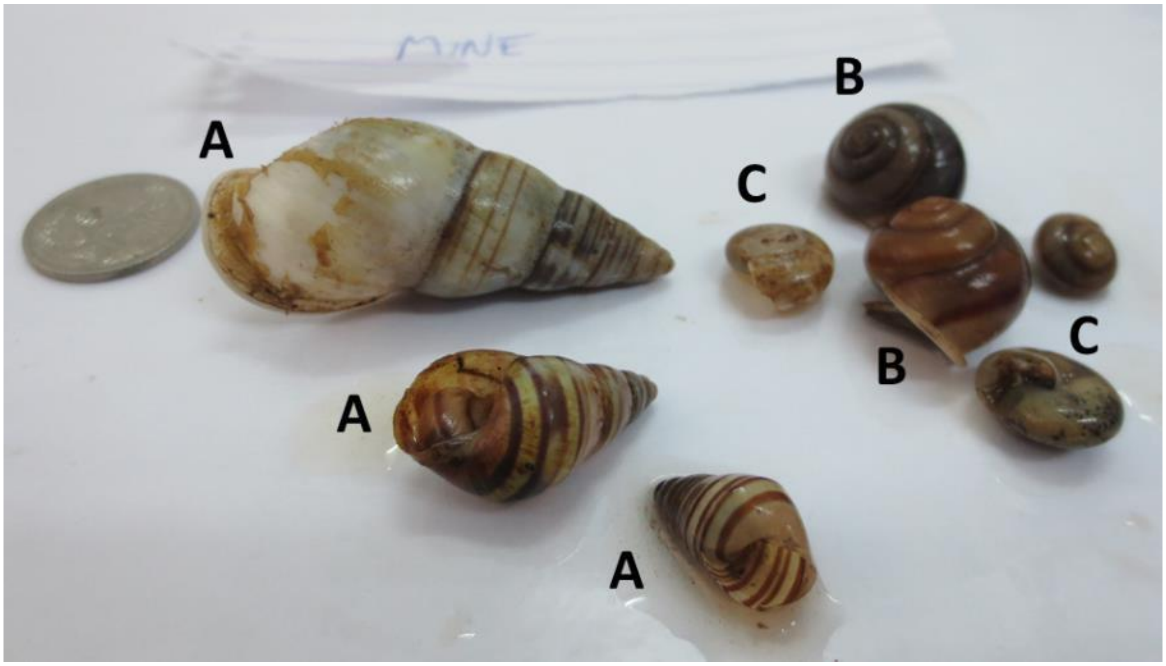

Figure 47. Landsnail taxa collected on the Mine site: A= Amphidromus c.f. contrarius (Family Camaenidae); B= Parachloritis c.f. newtoni (or possibly baucauensis); C= Macrochlamys sp. (Family Helicarionidae).

Figure 48. Landsnail taxa collected on the Clay Mine: A= **Parachloritis** ***c.f.*** **newtoni** ***(or possibly*** **baucauensis*****)*** ***(Family Camaenidae); B=*** **Amphidromus** ***c.f.*** **contrarius** ***(Family Camaenidae).***

PLANT SITE

Fauna habitat description

The Plant Site consisted predominantly of open woodland, mainly dominated by *Eucalyptus alba* to 10 m, or mixed woodland with *Schleichera oleosa* with a grassy or weedy ground cover. It was generally under high grazing pressure with large flocks of sheep and free range horses noted in the site. Overall it provided relatively low to moderate fauna habitat quality because it lacked Closed Tropical Forest, had limited vegetation structure, had limited canopy cover and an absence of sharp topographic relief, cliffs, caves, logs and leaf litter.

Fauna composition and significance

The only globally Near threatened species recorded in the Plant was Cinnamon-banded Kingfisher (*Halcyon australasia*) which is generally considered a Closed Tropical Forest specialist, but can also use *Eucalyptus alba* savanna woodland. Otherwise a highly generalized fauna was recorded including open country-woodland birds such as Barred Dove (*Geopelia maugeus*), Streak-breasted Honeyeater (*Meliphaga reticulata*), the two widespread introduced geckos (Tokay Gecko and House Gecko), flocks of about 35 sheep and several horses.

MINE SITE

Fauna habitat description

The Mine site covers approximately 400 hectares over an elevation range of 100-400 m, and is typified by a series of layered platforms. This site was dominated by savanna woodland usually 8-14 m tall with <30% canopy cover particularly dominated by *Eucalyptus alba*, *Schleichera oleosa* or both species, with a grassy or weedy ground cover. In some areas there was increased canopy cover usually of *Schleichera oleosa*. Rock cover was high, but these were often embedded in soil, with no cliffs, caves or particularly rugged rock outcrops observed which can form key refuges for reptiles, mammals and landsnails. Few tree hollows were noted. Weed cover was particularly high in well-grazed woodland (sheep, horse and buffalo).

Fauna composition and significance

The Mine site had a typical woodland-open country fauna comprising mostly introduced or tramp amphibian and reptile species. Five insectivorous bat species were recorded. Microhabitats such as Water Buffalo wallows may increase opportunities for introduced and invasive Black-spined Toad to breed. This invasive toad was commonly observed in the study area, and especially on roads just outside the study area. The bird fauna consisted of a mixture of woodland-open country species and several forest specialized birds. A total of five of the six Near threatened birds recorded during the surveys were recorded on the Mine and in total 14 globally restricted-range species were recorded. Many of these were non-forest species, but the Cinnamon-banded Kingfisher, Timor Oriole *Oriolus melanotis* and Timor Figbird *Sphecotheres viridis* are typically considered as forest specialist bird species.

CLAY MINE

Fauna habitat description

Three main fauna habitats were found on the Clay site: Closed Tropical Forest/bamboo, open shrubland (heavily degraded on clay) and ricefield paddies. The Closed Tropical Forest/bamboo was tall (to 20 m) with extensive canopy (to 80%), with logs, extensive litter, usually low rock cover providing high quality habitat for fauna. Open habitats such as open shrubland and ricefield paddies provided habitat for few bird species, typically open country species, and were categorized as having low to moderate fauna habitat quality. There was infiltration of some forest specialized birds during point counts in open shrubland though this was a scale issue (inclusion of birds within a 50 m radius) rather than shrubland providing habitat for forest birds.

Fauna composition and significance

There was a strong patterns in fauna habitat use, with Closed Tropical Forest/bamboo hosting numerous forest specialized bird species such as Timor Stubtail (*Urosphena subulata*), Black-backed Fruit-dove (*Ptilinopus cinctus*), Pink-headed Imperial Pigeon (*Ducula rosacea*) and Buff-banded Thicketwarbler (*Buettikoferella bivittata*). Twelve forest birds were only recorded on the Clay mine (Appendix 4). Nine of the 10 insectivorous microbats recorded during the overall study were present, mostly in Closed forest, or riverine bamboo thickets. Many forest specialized birds were also recorded from point count samples in open shrubland where in close proximity to fringing Closed Tropical Forest, but these spilled over from Closed Tropical Forest rather than being present in shrubland. Open habitats with little to no canopy cover and few trees such as the open shrubland and ricefield paddies provided low to very low quality fauna habitat. The relatively newly introduced Black-spined Toad occurred widely at the Clay site especially in riparian situations, along stream channels, riparian bamboo thickets and irrigation channels.

Discussion

Vegetation

A total of 22 vegetation surveys were conducted across the four main sites. The key vegetation structural formations surveyed can be broadly described as either “closed forest” systems or “open woodland” systems. The Closed Tropical Forest systems predominantly occur in the drainage lines, gullies and more sheltered areas and exhibit a higher soil moisture level, compared to the adjacent open woodland. The majority of the Closed Tropical Forest systems occurred as isolated patches within the mine and plant site and do not form contiguous bands. *Peltophorum pterocarpum* was the most frequently occurring species in the Closed Tropical Forest environments.

The clay mine site had a significantly higher proportion of contiguous Closed Tropical Forest, particularly on the eastern side of the site. These areas were not however uniform vegetation assemblages but rather variants, including bamboo forest areas, reflecting different elevation, soil and aspect. Across the survey group, the Closed Tropical Forest systems varied in their level of degradation, relative to the edge effects of invasive weeds and whether grazing animals, goats and buffalo, had easy access. All sites were influenced to some degree by invasive weeds. In general, the Closed Tropical Forest systems demonstrated higher plant species richness and diversity and were slightly less degraded than most open woodland sites. The clay mine site was characterised by severely degraded open woodland sections on hills and rises between more species rich pockets of Closed Tropical Forests.

The mine site is predominantly a uniform assemblage of open woodland species, typified by *Eucalyptus alba* (local name Bubu) and *Schleichera oleosa* with limited species diversity. Most survey sites on open woodland had high levels of disturbance from invasive weeds, most notably *Chromolaena odorata* and *Lantana camara.* Grazing pressure was also evident at many locations. The persistence of weeds in the environment has diminished the diversity of the lower and middle stratum throughout most of the open woodland sites.

The open woodland species found during the survey are well represented in Timor-Leste, though the limestone rich nature of soils at the mine site supports a slight variation in assemblage which includes *Acacia leucophloea,* but unfortunately also favours *Lantana camara*.

All survey locations included a high percentage of invasive species, most notably *Tecoma stans* (Yellow Bells)*, Lantana camara*, *Hyptis sauveolens* (Hyptis), *Chromolaena odorata* (Siam Weed) and *Ziziphus mauritiana* (Chinee Apple). Lesser sections of *Acacia nilotica* (Prickly Acacia) and *jatropha gossypifolia* (Bellyache Bush) were also recorded. Four of the introduced species recorded in the survey are listed as “Alien” on the Interim List of prohibited Invasive species (see www.laohamutuk.org/Agri/EnvLaw/div/SpeciesLists.pdf.).

Overall the most diverse sites recorded were at MI04-001 (NW corner of mine site) and at P002 (Plant Site). The highest basal factors recorded, in excess of $4m^2$ per hectare, were in areas with the least amount of weed disturbance (Figure 49). The highest basal factor recorded (highest density of mature trees) was a Closed Tropical Forest at TP01-001 on the clay mine site and at MI01-001 on the mine which was a relatively undisturbed open woodland site.

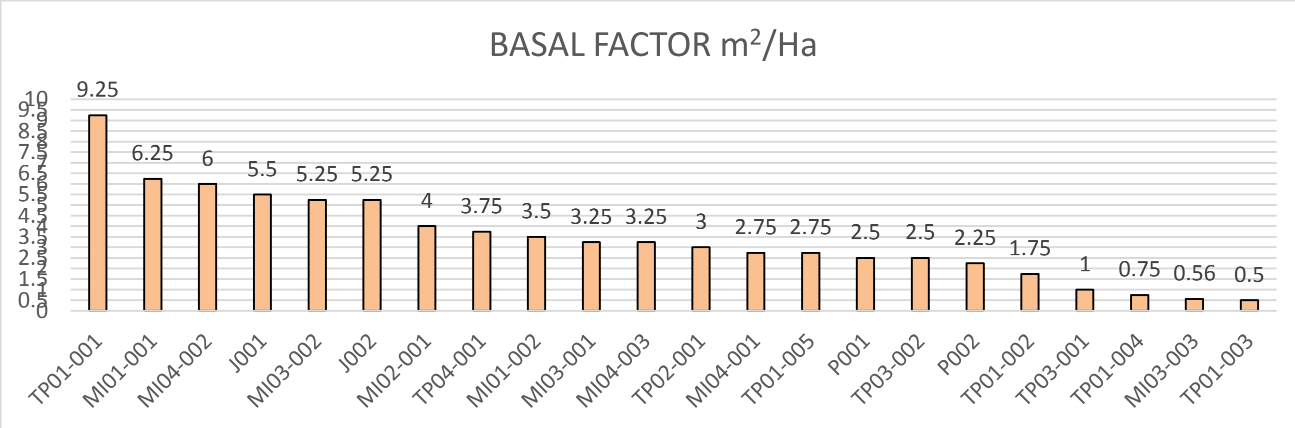

Figure 49. Total basal factor per survey site

Of the 71 plant species recorded during the survey, three species are listed under the IUCN Red List as Vulnerable. These were Sandalwood (*Santalum album*) recorded at the mine, Rosewood (*Pterocarpus indicus*) recorded at Clay mine and Burmese Teak (*Intisa bijuga*) also recorded at the Clay mine. The status of these species is poorly known in Timor-Leste. Sandlewood occurs in the broadest range of habitats, and recently has been widely planted through the country by the Ministry of Agriculture and Fisheries. Rosewood and Burmese Teak were recorded by Whistler (2001) in the Tutuala area; all three species were recorded in Nino Conis Santana National Park by Cowie (2006); and none of these three species were recorded by Worley Parsons (2012) in the Suai area. These three trees and an additional four plant species are listed on the Timor-Leste draft Interim List of Protected species (see www.laohamutuk.org/Agri/EnvLaw/div/SpeciesLists.pdf.).

Most sites exhibited medium to high levels of disturbance from invasive weeds and grazing pressure. The mine site was predominantly open woodland (Figure 50) which is well represented in other parts of Timor-Leste. The mine site includes some species rich patches of Closed Tropical Forest, primarily located within drainage floors, gullies and minor ravines. However, none of the Closed Tropical Forest environments on the mine site are contiguous and preservation would be largely ineffective if mining operations fully surrounded these areas. The woodland on the southern portion of the site is at a higher elevation and is largely contiguous and has a higher basal area than the northern portion of the site.

The Plant site has some isolated patches of Closed Tropical Forest but in general was heavily degraded with invasive weeds (Figure 50). The Jetty site is largely plantation vegetation and is severely degraded from invasive weeds.

The clay mine has the largest stands of relatively intact Closed Tropical Forest systems, especially along the eastern side of the site (Figure 51). The western side of the clay mine site had relatively low species diversity and higher levels of degradation.

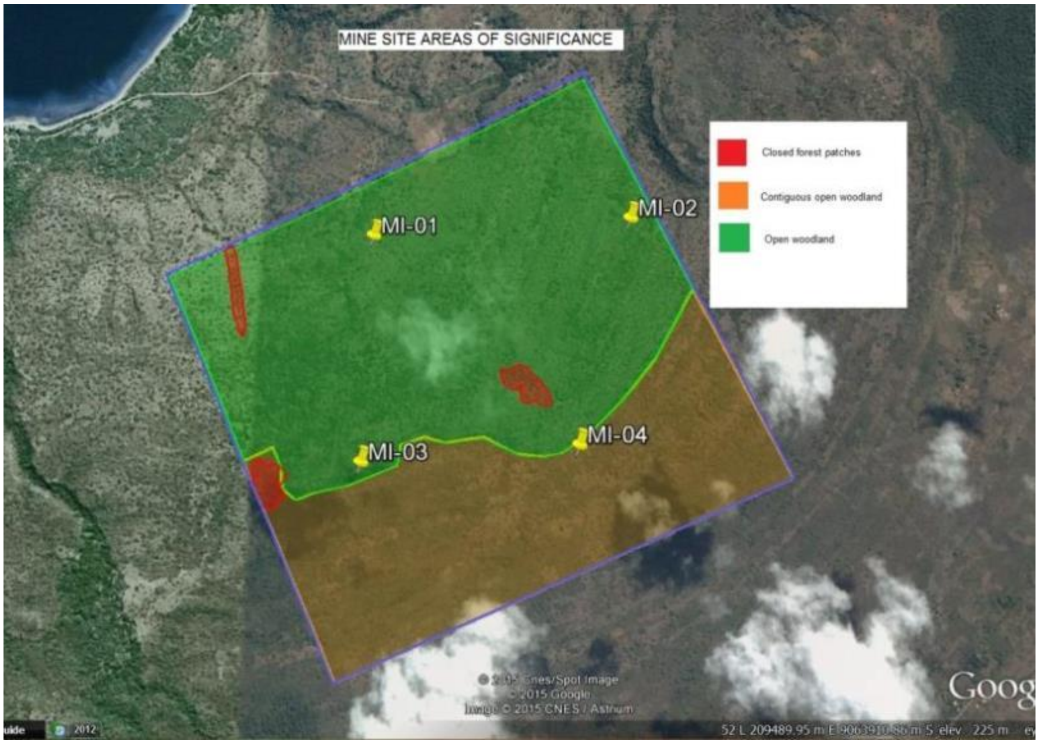

Figure 50: Mine Site Areas of Significance. (Image sourced from Google Earth)

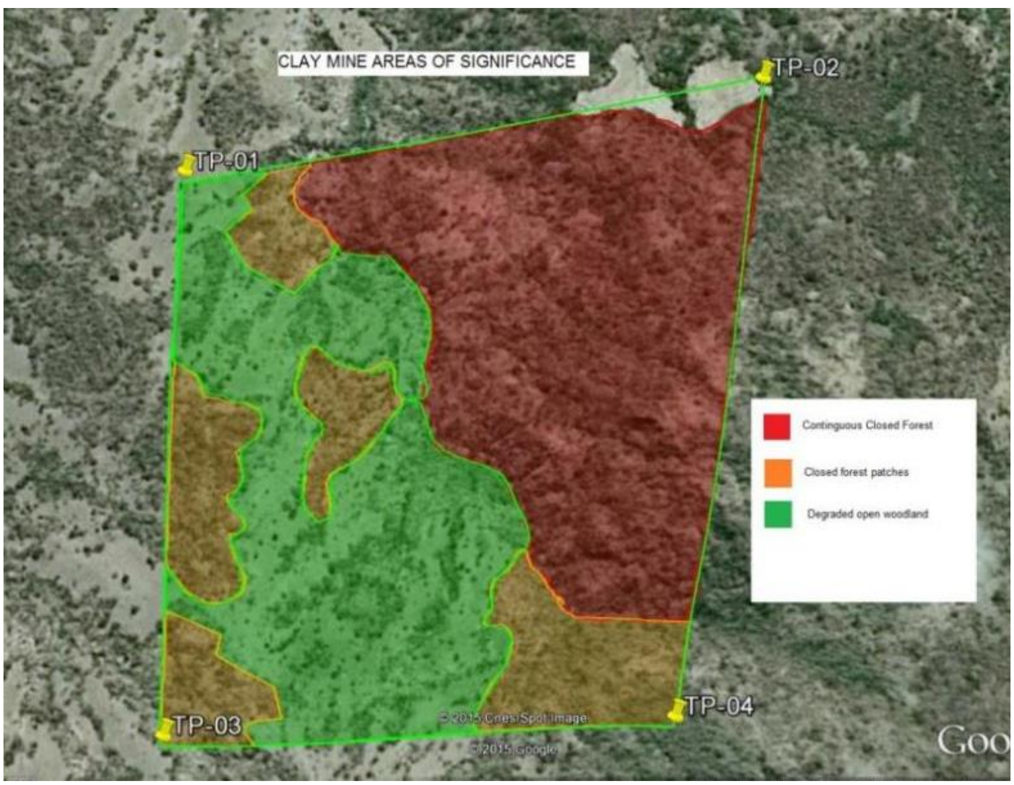

Figure 51: Clay Mine Areas of Significance. (Image sourced from Google Earth)

National and regional context

There has been no national mapping of vegetation communities in Timor-Leste, and relatively few published botanical surveys making it difficult to place survey results into a regional or national context. Woodland or open woodland communities occur widely in Timor-Leste, covering c. 3,933 km^2 (Sustainable Land Management Project: Grantham et al. 2011). Despite description of its occurrence in Timor-Leste by Martin and Cassalter (1977) there has been no specific mapping of *Eucalyptus alba* but it is relatively restricted and covers c.5-7% of the country (<c.600 km^2). Monk *et al.* (1997) state that *Eucalyptus alba* is a "dominant savanna type in Timor". The occurrence of *Eucalyptus* woodlands in the Baucau region was described by Martin and Cossalter (1977):

> *The plateau of Baucau lies in the eastern limit of this vast stretch of E.alba. This species forms near the airport an extensive but not very dense stand, consisting of only 6 to 7 trees to the ha on average. The average height is only about 16 m. The low density is due to the rocky nature of the soil, which is covered in places with a thin, red-brown layer of a clayey type. In association with E. alba there are a few Aleurites moluccana and Sterculia foetida.*

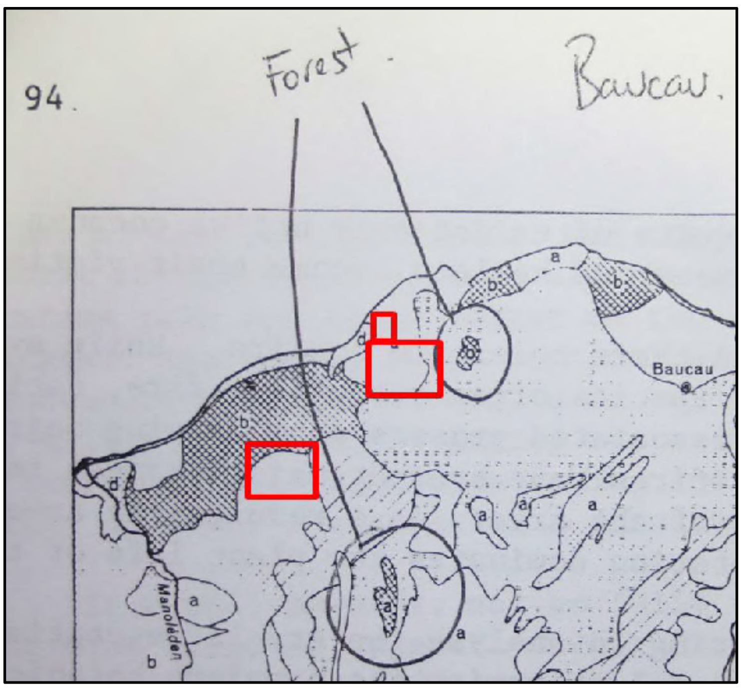

Figure 52. Vegetation classification covering the Baucau study region by Metzner (p.94; 1977; ©Metzner 1977); approximate location of study areas shown in red.

The regional vegetation classification and mapping exercise by Metzner (1977) mapped the general vicinity of the Jetty, Plant and Mine as "*Eucalyptus alba* savanna" and the vicinity of the Clay mine as "Forest-savanna mosaic" (Figure 52). Metzner (1977) notes that the *Eucalyptus alba* savanna was monodominated by an open tree layer of *Eucalyptus* up to 15-20 m tall, which was dominant in regularly burnt areas. The Forest-savanna mosaic was described as forest that has been partially destroyed by fire and cultivation with the proportions of tropical forest or savanna species depending on land use history (Metzner 1977). These habitat characterizations broadly agree with our vegetation classification, with the Forest-savanna mosaic capturing the present-day patchy distribution of Closed Tropical Forest on the Clay Mine.

Fauna

The fauna was highly typical of lowland woodland habitats on Timor in particular, dominated by wide-ranging and non-native amphibians (Black-spined Toad), reptiles (most regularly recorded species were introduced Tokay Gecko and House Gecko), and mammals (particularly livestock), numerous typical native woodland-open country bird species (e.g. Barred Dove, Spotted Dove, Pied Bushchat, White-shouldered Triller *Lalage sueurii*, Plain Fairy-warbler *Gerygone inornatus*, Indonesian Honeyeater *Lichmera limbata*) and a small set of forest specialized birds (Cinnamon-banded Kingfisher, Timor Oriole and Timor Stubtail).

Numerous microbat species were recorded whose taxonomy, habitat use and distribution in Timor-Leste remain poorly-known. There was no evidence in the study areas of the presence of four bat taxa that are potentially new to science—*Harpiocephalus* aff. *harpia*, *Kerivoula* sp., *Murina* aff. *florium*, *Rhinolophus* aff. *philippinensis* (Armstrong & Konishi 2015). We recorded an undescribed species of Rice Paddy Frog *Fejervarya*, which appears to occur widely in suitable ricefield/wetland habitat in Timor-Leste and two species of undescribed lowland *Carlia* skinks whose ecology is essentially unknown (O'Shea *et al.* 2015). Two mammals of conservation significance were recorded - the Vulnerable Canut's Horshoe Bat and Data Deficient Kai Horshoe Bat. The distribution and status of Canut's Horshoe Bat is poorly known but there are records from Nino Konis Santana National Park (Armstrong 2006) and the Suai area (Worley Parsons 2012). Up to a eight out of ten echolocating bat species recorded on the survey use caves for daytime roosting. The fauna survey was dominated by birds which comprised more than 90% of systematic fauna species recorded during point count sample data (Figure 15).

Overall we recorded c.33% of the amphibians known from Timor-Leste, c.16% of the reptiles, c.42% of the mammals and 44% of the resident landbirds (excluding waterbirds, migrant and visiting birds which were unrecorded in the terrestrial habitats of the study area) known from Timor-Leste (Figure 53). Three landsnail species were also recorded: three species at the Mine and two species at the Clay mine (Figs 30, 47 & 48). One reptile (Tokay Gecko *Gekko gecko*), four echolocating bats and 27 bird species are listed on the Timor-Leste draft Interim List of Protected species. In addition, the Black-spined Toad is listed as "Alien" on the draft Interim List of prohibited Invasive species (see www.laohamutuk.org/Agri/EnvLaw/div/SpeciesLists.pdf.)

Many terrestrial vertebrate fauna species would be absent from the study areas because of lack of specific habitat features, because they are geographically restricted to particular localities within Timor-Leste, or because of lack of trapping or particular specialized survey techniques (e.g. pitfall trapping, bat trapping).

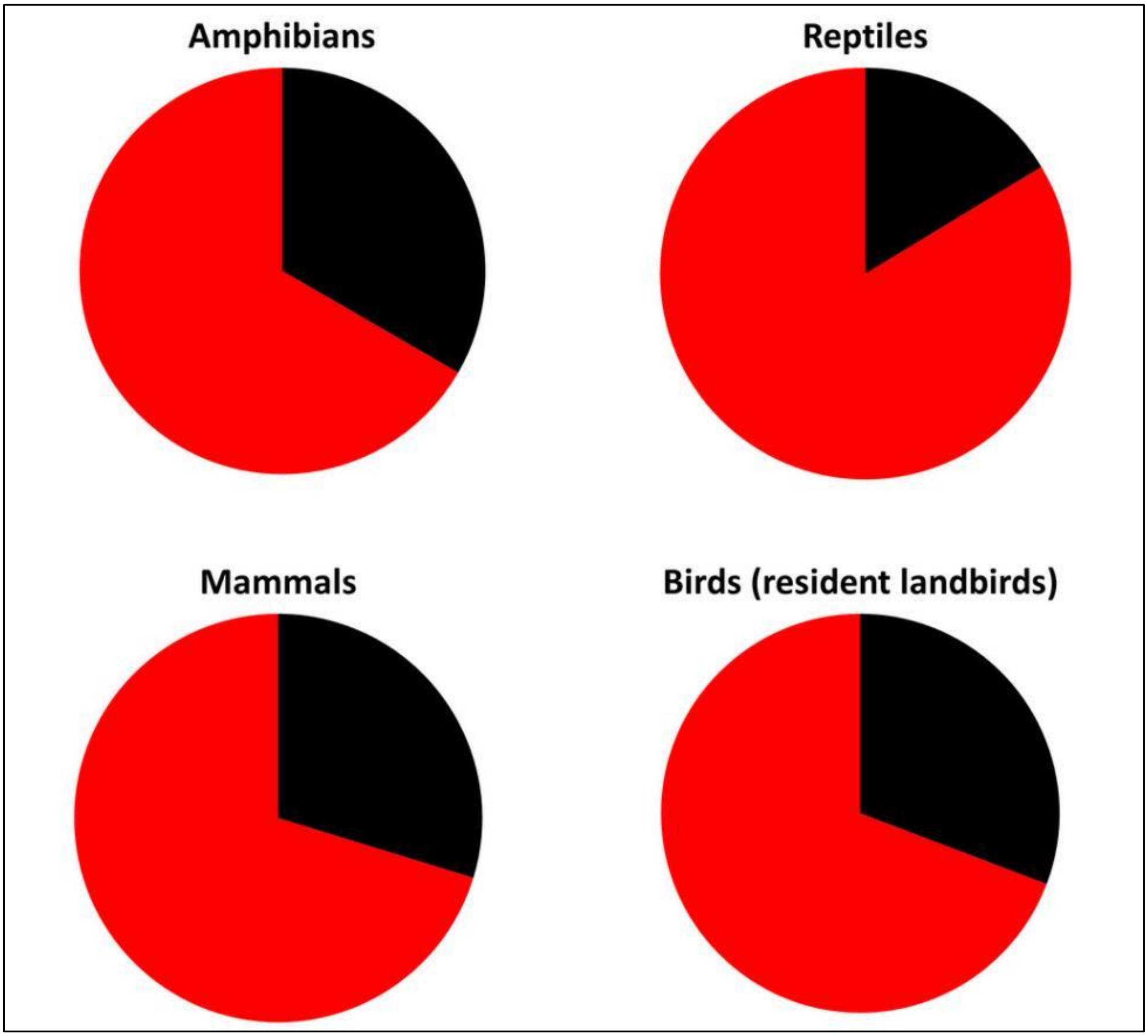

Figure 53. Summary of fauna species recorded: the proportion of amphibians (two of six species), reptiles, (eight of c. 41 species), mammal (22 of c. 52 species) and resident landbirds (56 of 126 species) species recorded during the survey and the number of additional species known from Timor-Leste and Timor Island (total number of species is approximate only for amphibians, reptiles and mammals, in particular, and includes undescribed taxa (c.f. O'Shea et al. 2015).

All bird species recorded at the Jetty, Plant and Mine were also recorded at the Clay mine, but 13 forest specialist bird species (Banded Fruit-Dove *Ptilinopus cinctus*, Pink-headed Imperial Pigeon *Ducula rosacea*, Marigold Lorikeet *Trichoglossus capistratus*, Wallacean Drongo, Timor Stubtail, Buff-banded Thicketwarbler, Timor Blue Flycatcher *Cyornis hyacinthinus*, Arafura Fantail *Rhipidura dryas*, Yellow-throated Whistler *Pachycephala macrorhyncha*, Spectacled Monarch *Symposiachrus trivirgatus*, Broad-billed Flycatcher *Myiagra ruficollis*, Black-breasted Myzomela *Myzomela vulnerata* and Tricolored Parrotfinch *Erythrura tricolor*) were only recorded at the Clay mine, highlighting the importance of Closed Tropical Forest for forest specialized bird species (Figures 15, 54; Appendix 4).

The Pink-headed Imperial Pigeon is probably under greater threat than all of the songbirds (passerines) listed because it is a large-bodied species targeted by hunters. It is also threatened by forest loss.

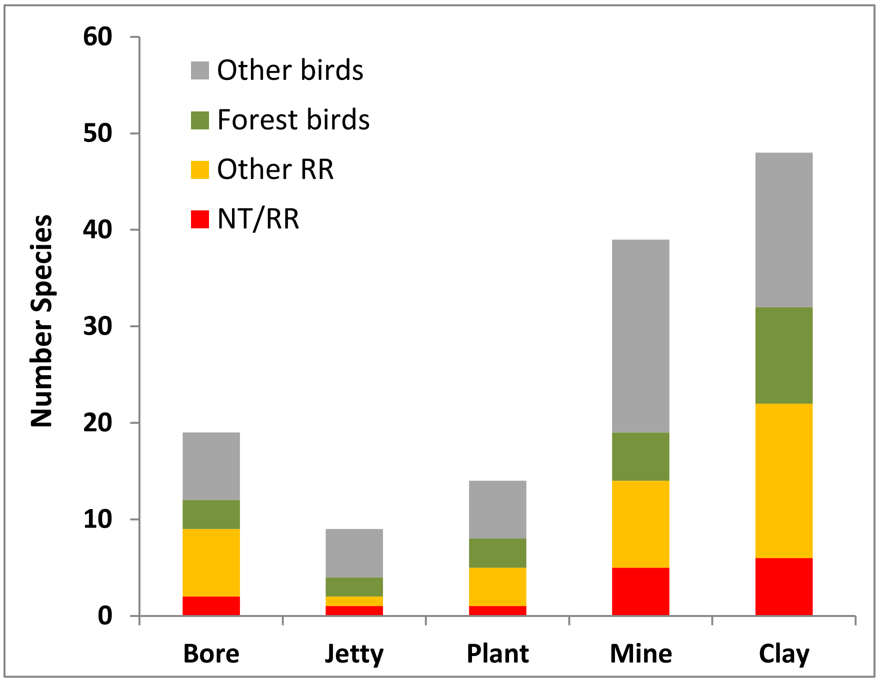

Figure 54. Broad patterns in bird species composition at study sites: NT/RR= Globally Near threatened birds species which are also restricted-range species; Other RR= other restricted-range bird species; Forest birds= forest specialized birds and Other birds= wide-ranging species that are not Near threatened, restricted-range or forest specialized. Note that there was unequal survey effort between sites.

Recommendations

The status of Closed Tropical Forest is poorly mapped and defined in Timor-Leste, but is clearly the richest and most biologically important vegetation type in Timor-Leste (c.f Cowie 2006, Trainor 2007ab). Closed Tropical Forest in the Mine, Plant and Clay sites hosts three IUCN listed threatened tree species and forest specialized bird species including at least six Near threatened species and is therefore of high biological significance. Reducing impacts to Closed Tropical Forest, particularly at the Clay site, would be valuable to avoid or reduce disturbance to more specialized Closed Tropical Forest tree species and associated fauna which are considered threatened or Near threatened primarily by loss or conversion of tropical forest habitat. No caves were located during the survey but several biologically and culturally significant caves (e.g. Bui Cere and Lie Sire) lie just to the east of the study area (Glover 1986). Such caves are vital for cave roosting bats. Aggregations of cave roosting bats are vulnerable to disturbance and increased rates of mortality in these places of refuge.

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Australian Plant Image Index Australian National Botanic Gardens Australian National Herbarium *https://www.anbg.gov.au/photo/apii/genus/Canavalia*

ABRS Flora of Australia Online

Australian Tropical Rainforest Plants: Edition 6: Trees shrubs vines herbs; grasses, sedges, palms, pandans and epiphytes. © CSIRO 2010 www. keys.trin.org.au:8080/.../Html/taxon/Timonius_timon_var._timon.htm

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Appendix 1. Vegetation and habitat characteristics at the 23 systematic quadrat samples.

TL CEMENT - VEGETATION FIELD SURVEY

SURVEY SITE NAME: Mine Site **DATE:** 22-05-15 **SITE No #** MI01-001

ZONE 52L **UTM COORDINATES:** 0208478 E 9064071 S **ELEVATION:** 120m
VEGETATION TYPE: OPEN WOODLAND
% LITTER <10% **% GRAVEL** <5% **%BARE** <15% **% WEEDS** 45%
SOIL TYPE: Loam **BASAL FACTOR:** 6.25m^2/ha
NOTES: Very open woodland, limestone pebbles, little to no mid storey, mixed grasses, herbs and weeds

VEGETATION

STRATUM	SPECIES	COVERAGE %	HEIGHT RANGE (m)
UPPER	*Eucalyptus alba*	<5%	10-12m
MIDDLE	*Chromolaena odorata*, *E. alba* juveniles	<5%	<1m
LOWER	*Hyptis suaveolens*, *Jatropha gossypifolia*	45%	

IUCN LISTED SPECIES

None recorded

INVASIVE SPECIES

Hyptis suaveolens, *Jatropha gossypifolia*

SURVEY SITE NAME: MINE SITE **DATE:** 22-05-15 **SITE No #** MI01-002

ZONE 52L **UTM COORDINATES:** 0208677 E 9064129 S **ELEVATION:** 126m
VEGETATION TYPE: OPEN WOODLAND
% LITTER 20% **% GRAVEL** <10% **%BARE** <10% **% WEEDS** 40%
SOIL TYPE: Loam **BASAL FACTOR:** 3.50m^2/ha
NOTES: Open woodland with grassy weed understory, broken limestone outcrops with exposed platforms

VEGETATION

STRATUM	SPECIES	COVERAGE %	HEIGHT RANGE (m)
UPPER	*Eucalyptus alba*, *Schleichera oleosa*,	<5%	6-10m
MIDDLE	*Eucalyptus alba* juveniles , *Ziziphus mauritiana*, *Chromolaena odorata*	20%	
LOWER	*Pithecellobium dulcis*, *Hyptis suaveolens*, *Acacia nilotica* seedlings		

IUCN LISTED SPECIES

None recorded

INVASIVE SPECIES

Ziziphus mauritiana, *Chromolaena odorata*, *Acacia nilotica*, *Jatropha gossypifolia*

TL CEMENT - VEGETATION FIELD SURVEY

SURVEY SITE NAME: MINE SITE **DATE:** 22-05-15 **SITE No #** MI02-001

ZONE 52L **UTM COORDINATES:** 0209399 E 9064168 S **ELEVATION:** 195m
VEGETATION TYPE: OPEN WOODLAND
% LITTER <10% **% GRAVEL** <10% **%BARE** 10% **% WEEDS** 15%
SOIL TYPE: Loam **BASAL FACTOR:** 4.00m^2/ha
NOTES: Open woodland, very representative, slightly degraded with frequent limestone outcrops

VEGETATION			
STRATUM	**SPECIES**	**COVERAGE %**	**HEIGHT RANGE (m)**
UPPER	*Eucalyptus alba*, *Schleichera oleosa*	<5%	8-10m
MIDDLE	*E. alba* juveniles,		<1m
LOWER	*Iseilema minutiflorum*, *Hyptis suaveolens*, *Indigofera linifolia*, *Chromolaena odorata*		
OTHER SPECIMENS			

IUCN LISTED SPECIES

Indigofera linifolia – Least Concern

INVASIVE SPECIES

Hyptis suaveolens, *Chromolaena odorata*

TL CEMENT - VEGETATION FIELD SURVEY

SURVEY SITE NAME: MINE SITE **DATE:** 21-05-15 **SITE No #** MI03-001

ZONE 52L **UTM COORDINATES:** 0208405 E 9063108 S **ELEVATION:** 231m
VEGETATION TYPE: OPEN WOODLAND
% LITTER <5% **% GRAVEL** <15% **%BARE** >10% **% WEEDS** 20%
SOIL TYPE: SANDY LOAM **BASAL FACTOR:** 3.25 m^2/ha
NOTES: adjacent forest, high level weed disturbance.

VEGETATION			
STRATUM	**SPECIES**	**COVERAGE %**	**HEIGHT RANGE (m)**
UPPER	*Eucalyptus alba*, *Santalum album*, *Schleichera oleosa*	<5%	10-12m
MIDDLE	*Lantana camara*, *Chromolaena odorata*, *Hyptis suaveolens*	<5%	1-2m
LOWER	Grasses with mixed herbs, *Iseilema minutiflorum*, *Indigofera* spp.	40%	
OTHER SPECIMENS	*Senna occidentalis*		

IUCN LISTED SPECIES

Santalum album – Vulnerable, *Indigofera* spp – *(poss; linifolia)* – Least Concern

INVASIVE SPECIES

Lantana camara, *Hyptis suaveolens*, *Chromolaena odorata*

SURVEY SITE NAME: MINE SITE **DATE:** 21-05-15 **SITE No #** MI03-002

ZONE 52L **UTM COORDINATES:** 0208341 E 9063186 S **ELEVATION:** 216m
VEGETATION TYPE: Open woodland
% LITTER 20% **% GRAVEL** <5% **%BARE** <5% **% WEEDS** 15%
SOIL TYPE: **BASAL FACTOR:** 5.25 m^2/ha
NOTES: North aspect slopes with limestone outcrops and extensive grass cover

VEGETATION			
STRATUM	**SPECIES**	**COVERAGE %**	**HEIGHT RANGE (m)**
UPPER	*Eucalyptus alba*, *Alstonia actinophylla*, *Gmelina arborea*, *Schleichera oleosa*	30%	7-15m
MIDDLE	*Eucalyptus alba* juveniles, *Tecoma stans*, *Ziziphus mauritiana*, *Chromolaena odorata*	10%	2-3m
LOWER	Grasses, *Imperata cylindrica*	90%	1-2m
OTHER SPECIMENS	*Dischidia major*, *Dischidia nummularlia* epiphytes		

IUCN LISTED SPECIES

None recorded

INVASIVE SPECIES

Tecoma stans, *Ziziphus mauritiana*, *Chromolaena odorata*

TL CEMENT - VEGETATION FIELD SURVEY

SURVEY SITE NAME: MINE SITE **DATE:** 21-05-15 **SITE No #** MI03-003

ZONE 52L **UTM COORDINATES:** 0208631 E 9063376 S **ELEVATION:** 203m
VEGETATION TYPE: OPEN FOREST SLOPING TO CLOSED FOREST
% LITTER 15% **% GRAVEL** <5% **%BARE** <5% **% WEEDS** 30%
SOIL TYPE: Limestone **BASAL FACTOR:** 0.56 m^2/ha
NOTES: Limestone outcrops

VEGETATION			
STRATUM	**SPECIES**	**COVERAGE %**	**HEIGHT RANGE (m)**
UPPER	*Eucalyptus alba*, *Schleichera oleosa*, Senna timoriensis	10%	10-12m
MIDDLE	*Tecoma stans*, *Chromolaena odorata*, *Ziziphus mauritiana*	30%	1.5m
LOWER	*Hyptis suaveolens*, Grewia sp, grasses	90%	1m

IUCN LISTED SPECIES

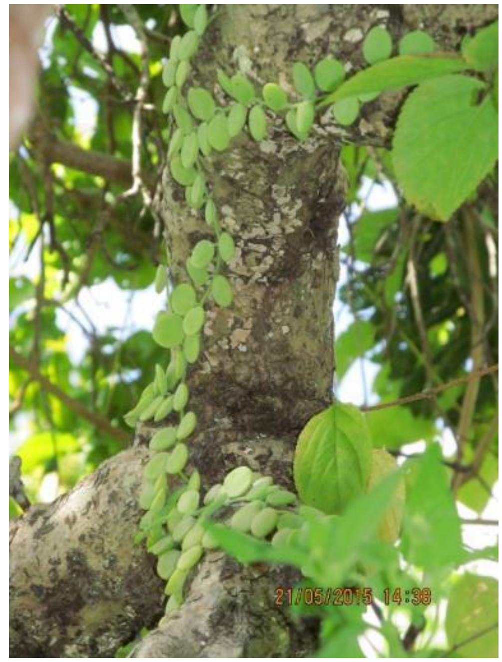
None recorded

INVASIVE SPECIES

Tecoma stans, *Chromolaena odorata*, *Ziziphus mauritiana*, *Hyptis suaveolens*

TL CEMENT - VEGETATION FIELD SURVEY

SURVEY SITE NAME: MINE SITE **DATE:** 21-05-15 **SITE No #** MI04-001



ZONE 52L **UTM COORDINATES:** 8209239 E 9063534 S **ELEVATION:** 234m
VEGETATION TYPE: CLOSED FOREST
% LITTER >15% **% GRAVEL** <10% **%BARE** <10% **% WEEDS** 20%
SOIL TYPE: Loam **BASAL FACTOR:** 2.75 m^2/ha
NOTES: Gully slope with limestone outcrops

VEGETATION			
STRATUM	**SPECIES**	**COVERAGE %**	**HEIGHT RANGE (m)**
UPPER	*Schleichera oleosa*, *Tecoma stans*, *Santalum album*, *Cryptocarya foetida*	30%	8m
MIDDLE	*Wrightia pubescens*, *Dichapetalum timorense*, *Vanda insignis*, *Dischidia major*, *Dischidia nummularlia*	30%	2m
LOWER	*Uraria lagopodiodes*, *Breynia cernua*, *Iseilema minutiflorum*, *Lantana camara*, *Chromolaena odorata*, *Hyptis suaveolens*	70%	

IUCN LISTED SPECIES

Santalum album

INVASIVE SPECIES

Lantana camara, *Chromolaena odorata*, *Hyptis suaveolens*, *Tecoma stans*

TL CEMENT - VEGETATION FIELD SURVEY

SURVEY SITE NAME: MINE SITE **DATE:** 21-05-15 **SITE No #** MI04-002

ZONE 52L **UTM COORDINATES:** 0209080 E 9063669 S **ELEVATION:** 204m
VEGETATION TYPE: OPEN WOODLAND
% LITTER >20% **% GRAVEL** <5% **%BARE nil** **% WEEDS** 5%
SOIL TYPE: Loam **BASAL FACTOR:** 6.00 m^2/ha
NOTES: Minimal disturbance from weeds

VEGETATION			
STRATUM	**SPECIES**	**COVERAGE %**	**HEIGHT RANGE (m)**
UPPER	*Eucalyptus alba*, *Alstonia actinophylla*, *Pometia pinnata*	5%	6-8m
MIDDLE	*E. alba* juveniles	<5%	to 2m
LOWER	*Imperata cylindrica*, *Grewia* sp. *Phyllanthus virgatus*, *Justicia procumbens*, *Iseilema minutiflorum*	90%	1m

IUCN LISTED SPECIES

None recorded

INVASIVE SPECIES

Lantana camara, *Chromolaena odorata*

TL CEMENT - VEGETATION FIELD SURVEY

SURVEY SITE NAME: MINE SITE **DATE:** 21-05-15 **SITE No #** MI04-003

ZONE 52L **UTM COORDINATES:** 0208914 E 9063924 S **ELEVATION:** 150m
VEGETATION TYPE: CLOSED FOREST
% LITTER >20% **% GRAVEL** <10% **%BARE** <10% **% WEEDS** 60%
SOIL TYPE: Loam **BASAL FACTOR:** 3.25 m^2/ha
NOTES: Heavily disturbed closed forest with *Chromolaena odorata* and adjacent grassland. Limestone outcrops

VEGETATION			
STRATUM	**SPECIES**	**COVERAGE %**	**HEIGHT RANGE (m)**
UPPER	*Eucalyptus alba*, *Dalbergia timoriensis*, *Acacia* sp.	40%	8-10m
MIDDLE	*E. alba* juveniles, *Chromolaena odorata*	<10%	1-2m
LOWER	Mixed grass, *Hyptis suaveolens*	40%	

IUCN LISTED SPECIES

None recorded

INVASIVE SPECIES

Chromolaena odorata, *Hyptis suaveolens*

TL CEMENT - VEGETATION FIELD SURVEY

SURVEY SITE NAME: PLANT SITE **DATE:** 22-05-15 **SITE No #** P001

ZONE 52L **UTM COORDINATES:** 0208103 E 9064628 S **ELEVATION:** 63m
VEGETATION TYPE: OPEN WOODLAND
% LITTER 10% **% GRAVEL** <5% **%BARE** 10% **% WEEDS** 60%
SOIL TYPE: Loam **BASAL FACTOR:** 2.50 m^2/ha
NOTES: Heavily disturbed and modified open woodland with weed understory and limestone outcrops and pebbles

NATIVE VEGETATION			
STRATUM	**FAMILY GENUS SPECIES**	**COVERAGE %**	**HEIGHT RANGE (m)**
UPPER	*Eucalyptus alba*, *Schleichera oleosa*	<5%	8-10m
MIDDLE	*E.alba* juveniles, *Ziziphus mauritiana*, *Chromolaena odorata*, *Canarium vulgare*, *Annona squamosa*,	20%	2-3m
LOWER	*Hyptis suaveolens*, *Jatropha gossypifolia*	40%	0-2m

IUCN LISTED SPECIES

None recorded

INVASIVE SPECIES

Hyptis suaveolens, *Chromolaena odorata*, *Jatropha gossypifolia*

TL CEMENT - VEGETATION FIELD SURVEY

SURVEY SITE NAME: PLANT SITE **DATE:** 22-05-15 **SITE No #** P002

ZONE 52L **UTM COORDINATES:** 0207981 E 9064378 S **ELEVATION:** 69m
VEGETATION TYPE: CLOSED FOREST
% LITTER 70% **% GRAVEL** <10% **%BARE** 10% **% WEEDS** 15%
SOIL TYPE: Loam **BASAL FACTOR:** 2.25 m^2/ha
NOTES: Closed forest in a minor depression bordered by lantana with isolated limestone outcrops

VEGETATION			
STRATUM	**SPECIES**	**COVERAGE %**	**HEIGHT RANGE (m)**
UPPER	*Tecoma stans*, *Intsia bijuga*, *Ficus* sp., *Muntingia calabura*, *Ziziphus oenopolia*, *Tamarindus indica*, *Senna timoriensis*, *Streblus asper*,	30%	10-15m
MIDDLE	Juveniles of upper stratum, *Lantana camara*, *Chromolaena odorata*	40%	1-3m
LOWER	Leaf litter, seedlings		

IUCN LISTED SPECIES

Intsia bijuga - Vulnerable

INVASIVE SPECIES

Lantana camara, *Jatropha gossypifolia*, *Chromolaena odorata*

TL CEMENT - VEGETATION FIELD SURVEY

SURVEY SITE NAME: CLAY MINE **DATE:** 25-05-15 **SITE No #** TP01-001

ZONE 52L **UTM COORDINATES:** 0202864 E 9059430 S **ELEVATION:** 206m
VEGETATION TYPE: CLOSED FOREST
% LITTER 40% **% GRAVEL** 0% **%BARE** 20% **% WEEDS** 10%
SOIL TYPE: LOAM **BASAL FACTOR:** 9.25 m^2/ha
NOTES: Closed forest with middle stratum, high soil moisture content, vines and tall trees.

VEGETATION			
STRATUM	**SPECIES**	**COVERAGE %**	**HEIGHT RANGE (m)**
UPPER	*Peltophorum pterocarpum*, *Ziziphus oenopolia*, *Ziziphus timoriensis*	40%	10-12m
MIDDLE	*Peltophorum pterocarpum*, *Ziziphus oenopolia*, *Ziziphus timoriensis* (juveniles), *Schleichera oleosa*, *Hibiscus hirtus*, *Lantana camara*	20%	1-3m
LOWER	*Citrus* sp,		

IUCN LISTED SPECIES

None recorded

INVASIVE SPECIES

Lantana camara

TL CEMENT - VEGETATION FIELD SURVEY

SURVEY SITE NAME: CLAY MINE **DATE:** 25-05-15 **SITE No #** TP01-002

ZONE 52L **UTM COORDINATES:** 0202801 E 9059179 S **ELEVATION:** 230m
VEGETATION TYPE: CLOSED FOREST
% LITTER <5% **% GRAVEL** 5% **%BARE** 10% **% WEEDS** 15%
SOIL TYPE: CLAY LOAM **BASAL FACTOR:** 1.75 m^2/ha
NOTES: Heavily disturbed site from clearing and grazing with numerous weeds dominating the middle stratum and limestone outcrops

VEGETATION			
STRATUM	**SPECIES**	**COVERAGE %**	**HEIGHT RANGE (m)**
UPPER	*Peltophorum pterocarpum, Pterocarpus indicus, Eucalyptus alba*	<5%	15m
MIDDLE	*Acacia nilotica, Lantana camara*	10%	1-3m
LOWER	*Thecanthes concreta*		

IUCN LISTED SPECIES

Pterocarpus indicus - Vulnerable

INVASIVE SPECIES

Acacia nilotica, Lantana camara, Chromolaena odorata

TL CEMENT - VEGETATION FIELD SURVEY

SURVEY SITE NAME: CLAY MINE **DATE:** 25-05-15 **SITE No #** TP01-003

ZONE 52L **UTM COORDINATES:** 0202375 E 9059053 S **ELEVATION:** 225m
VEGETATION TYPE: OPEN WOODLAND – HEAVILY DEGRADED GRASSLAND
% LITTER 0% **% GRAVEL** 20% **%BARE** 20% **% WEEDS** 30%
SOIL TYPE: CLAY LOAM **BASAL FACTOR:** 0.50 m^2/ha
NOTES: Heavily disturbed site from previous clearing.

VEGETATION			
STRATUM	**SPECIES**	**COVERAGE %**	**HEIGHT RANGE (m)**
UPPER	absent	0%	-
MIDDLE	*Acacia nilotica*	10%	2m
LOWER	*Thecanthes concreta*, *Indigofera linifolia*, *Iseilma minutiflorum*		

IUCN LISTED SPECIES

Indigofera linifolia – Least Concern

INVASIVE SPECIES

Acacia nilotica

TL CEMENT - VEGETATION FIELD SURVEY

SURVEY SITE NAME: CLAY MINE **DATE:** 22-05-15 **SITE No #** TP01-004

ZONE 52L **UTM COORDINATES:** 0202517 E 9059019 S **ELEVATION:** 249m
VEGETATION TYPE: CLOSED FOREST – HEAVILY DEGRADED
% LITTER <5% **% GRAVEL** <5% **%BARE** 20% **% WEEDS** 85%
SOIL TYPE: CLAY LOAM **BASAL FACTOR:** 0.75 m^2/ha
NOTES: Cleared closed forest that has become extensively infested with weeds

VEGETATION			
STRATUM	**SPECIES**	**COVERAGE %**	**HEIGHT RANGE (m)**
UPPER	*Peltophorum pterocarpum*	<5%	6m
MIDDLE	*Lantana camara, Chromolaena odorata*	80%	2m
LOWER	*Lantana camara, Chromolaena odorata, Iseilma minutiflorum*		

IUCN LISTED SPECIES
None recorded

INVASIVE SPECIES
Lantana camara, *Chromolaena odorata*

TL CEMENT - VEGETATION FIELD SURVEY

SURVEY SITE NAME: CLAY MINE **DATE:** 25-5-15 **SITE No #** TP01-005

ZONE 52L **UTM COORDINATES:** 0202426 E 9059249 S **ELEVATION:** 234m
VEGETATION TYPE: CLOSED FOREST
% LITTER 15% **% GRAVEL** 0% **%BARE** 5% **% WEEDS** 75%
SOIL TYPE: LOAM **BASAL FACTOR:** 2.75 m^2/ha
NOTES: Heavily disturbed/degraded closed forest with extensive weeds middle and lower stratum, some limestone outcrops.

VEGETATION			
STRATUM	**SPECIES**	**COVERAGE %**	**HEIGHT RANGE (m)**
UPPER	*Peltophorum pterocarpum, Hibiscus hirtus, Terminalia cattapa*	20%	10-15m
MIDDLE	*Peltophorum pterocarpum* (juvenile), *Chromolaena odorata*, *Lantana camara, Pometia pinnata*	40%	1-3m
LOWER	*Chromolaena odorata*, *Lantana camara*		

IUCN LISTED SPECIES

None recorded

INVASIVE SPECIES

Chromolaena odorata, *Lantana camara*, *Jatropha gossypifolia*

TL CEMENT - VEGETATION FIELD SURVEY

SURVEY SITE NAME: CLAY MINE **DATE:** 25-05-15 **SITE No #** TP02-001

ZONE 52L **UTM COORDINATES:** 0203914 E 9059565 S **ELEVATION:** 259m
VEGETATION TYPE: MODIFIED AGRICULTURAL
% LITTER <10% **% GRAVEL** 0% **%BARE** <5% **% WEEDS** 30%
SOIL TYPE: CLAY LOAM **BASAL FACTOR:** 3.00 m^2/ha
NOTES: This site falls within the oldest established farming are at the Clay Mine and is 100% modified for agriculture.

VEGETATION			
STRATUM	**SPECIES**	**COVERAGE %**	**HEIGHT RANGE (m)**
UPPER	*Psidium guajava*, *Mangifera indica*, *Musa* sp, *Gliricidia sepum*, *Ceiba pentandra*, *Leucaena leucocephala*, *Cocos nucifera*	5%	3-5m
MIDDLE	*Corypha utan*, *Chromolaena odorata*,		
LOWER	*Oryza* sp, *Senna occidentalis*		
OTHER SPECIMENS			

IUCN LISTED SPECIES
None recorded

INVASIVE SPECIES
Chromolaena odorata,

SURVEY SITE NAME: CLAY MINE **DATE:** 23-05-15 **SITE No #** TP03-001

ZONE 52L **UTM COORDINATES:** 0202730 E 9058244 S **ELEVATION:** 306m
VEGETATION TYPE: OPEN WOODLAND (DEGRADED)
% LITTER <10% **% GRAVEL** 5% **%BARE** 40% **% WEEDS** 25%
SOIL TYPE: CLAY **BASAL FACTOR:** 1.00 m^2/ha
NOTES: Exposed hill top, previously cleared woodland

VEGETATION			
STRATUM	SPECIES	COVERAGE %	HEIGHT RANGE (m)
UPPER	*Acacia leucophloea, Peltophorum pterocarpum*	<5%	8-12m
MIDDLE	*Acacia nilotica, Lantana camara*	10%	2m
LOWER	*Thecanthes concreta, Indigofera linifolia, Iseilma minutiflorum*		

IUCN LISTED SPECIES

Indigofera linifolia – Least Concern

INVASIVE SPECIES

Acacia nilotica, Lantana camara

SURVEY SITE NAME: CLAY MINE **DATE:** 23-05-15 **SITE No #** TP03-002

ZONE 52L **UTM COORDINATES:** 0202813 E 9058201 S **ELEVATION:** 315m
VEGETATION TYPE: CLOSED FOREST - BAMBOO
% LITTER <10% **% GRAVEL** 0% **%BARE** 5% **% WEEDS** 70%
SOIL TYPE: CLAY LOAM **BASAL FACTOR:** 2.50 m^2/ha
NOTES: Steep sloping bamboo forest to test pit No. 3 with adjacent creek.

VEGETATION

STRATUM	SPECIES	COVERAGE %	HEIGHT RANGE (m)
UPPER	*Dendrocalamus* sp, *Acacia leucophloea*, *Peltophorum pterocarpum*, *Pterocarpus indicus*, *Tectona grandis*, *Sesbania grandiflora*	20%	10-15m
MIDDLE	*Senna surattensis*, *Chromolaena odorata*, *Acacia nilotica*	<5%	2-3m
LOWER	*Gliricidia sepum*		

IUCN LISTED SPECIES

Pterocarpus indicus

INVASIVE SPECIES

Chromolaena odorata, *Acacia nilotica*

TL CEMENT - VEGETATION FIELD SURVEY

SURVEY SITE NAME: CLAY MINE **DATE:** 25-05-15 **SITE No #** TP04-001

ZONE 52L **UTM COORDINATES:** 0203759 E 9058277 S **ELEVATION:** 310m
VEGETATION TYPE: CLOSED FOREST - BAMBOO
% LITTER 80% **% GRAVEL** 0% **%BARE** <10% **% WEEDS** 35%
SOIL TYPE: LOAM CLAY **BASAL FACTOR:** 3.75 m^2/ha
NOTES: Closed bamboo forest with limited middle stratum, extensive leaf litter and weeds in understory.

VEGETATION			
STRATUM	**SPECIES**	**COVERAGE %**	**HEIGHT RANGE (m)**
UPPER	*Dendrocalamus* sp, *Tamarindus indica*, *Ceiba pentandra*	30%	8-10m
MIDDLE	*Chromolaena odorata*	<5%	1m
LOWER	*Desmodium gangeticum*, *Canavalia papuana*, *Ageratina riparia*, *Brucea javanica*	20%	

IUCN LISTED SPECIES

None recorded

INVASIVE SPECIES

Chromolaena odorata

TL CEMENT - VEGETATION FIELD SURVEY

SURVEY SITE NAME: JETTY **DATE:** 22-05-15 **SITE No #** J001

ZONE 52L **UTM COORDINATES:** 207740 E 9065527 S **ELEVATION:** 20m
VEGETATION TYPE: CLOSED FOREST - PALMS
% LITTER 50% **% GRAVEL** 0% **%BARE** 0% **% WEEDS** 50%
SOIL TYPE: SANDY **BASAL FACTOR:** 5.50 m^2/ha
NOTES: Tall palm forest with plantation species and dominant weed middle stratum

VEGETATION			
STRATUM	**SPECIES**	**COVERAGE %**	**HEIGHT RANGE (m)**
UPPER	*Borassus flabelifer*, *Corypha utan, Artocarpus integer, Tamarindus indica*	30%	20-30m
MIDDLE	*Lantana camara*, *Chromolaena odorata*	70%	2m
LOWER	absent		

IUCN LISTED SPECIES

None recorded

INVASIVE SPECIES

Lantana camara, *Chromolaena odorata*

TL CEMENT - VEGETATION FIELD SURVEY

SURVEY SITE NAME: JETTY **DATE:** 22-05-15 **SITE No #** J002

ZONE 52L **UTM COORDINATES:** 0207628 E 9065449 S **ELEVATION:** 22m
VEGETATION TYPE: CLOSED FOREST - PALMS
% LITTER 90% **% GRAVEL** 0% **%BARE** 0% **% WEEDS** 10%
SOIL TYPE: SANDY **BASAL FACTOR:** 5.25 m^2/ha
NOTES: Heavily modified plantation environment/degraded Beach forest with absent lower stratum, dominant breadfruit trees.

VEGETATION			
STRATUM	**SPECIES**	**COVERAGE %**	**HEIGHT RANGE (m)**
UPPER	*Artocarpus atilis, Persea americana, Cocos nucifera, Borassus flabelifer*	30%	25-30m
MIDDLE	*Lantana camara, Chromolaena odorata*	10%	2m
LOWER	absent		

IUCN LISTED SPECIES

None recorded

INVASIVE SPECIES

Lantana camara, Chromolaena odorata

Appendix 2. Complete plant species list recorded during field surveys, family, lifeform, local name, status (IUCN & Interim list of protected species) and systematic quadrat records.

Plant Species	Family	Form	Local name	Common name	Introduced /native	IUCN status	Interim list of protected species	Quadrat location
Acacia leucophloea syn *Vachellia leucophloea*	Fabaceae	Tree	Sia buto		Native?			TP03-001-1
Acacia nilotica syn *Vachellia nilotica*	Fabaceae	Tree			Introduced/weed			MI01-002
Acacia sp	Fabaceae	Small tree	Ai bercama					MI04-003-2
Ageratina riparia	Asteraceae (Eupatoriae)	Herb		Mist flower	Introduced/weed			TP04-001-13
Alstonia actinophylla	Apocynaceae	Tree			N			
Annona squamosa	Annonaceae	Tree	Ai ata					P001-7
Artocarpus altilis	Moraceae	Tree						
Artocarpus integer	Moraceae	Tree	Ai lemi	Chempedak	Native			J001 T3; J001-1
Borassus flabellifer	Arecaceae	Tree	Tali tahan					J001-T1
Breynia cernua	Phyllanthaceae	Small tree			Native			MI04-001-12
Brucea javanica	Simaroubaceae	Small tree						TP04-001-14
Canarium vulgare	Burseraceae	Tree	Kai tudo				✓	P001-6
Canavalia papuana	Fabaceae	Vine						TP04-001-12
Chromolaena odorata	Asteraceae (Eupatoriae)	Shrub		Siam weed	Introduced/weed		Alien	
Citrus sp. possibly gracilis ?	Rutaceae	Small tree	Kai wetu manu		Native?			TP01-001-11
Cocos nucifera	Arecaceae	Tree	Nu'u	coconut				
Corypha utan	Arecaceae	Tree	Akadiru					J001-T2
Cryptocarya sp (foetida?)	Lauraceae	Tree	Ai sten mean					MI04-001-2
Dalbergia timoriensis	Fabaceae	Tree	Tali putih					MI04-003
Dendrocalamus sp	Poaceae	Grass		Bamboo				TP04-001-1
Desmodium gangeticum	Fabaceae	Herb						TP04-001-11
Dichapetalum timorense	Dichapetalaceae	Tree						MI04-001-7
Dischidia major syn. rafflesiana	Asclepiadaceae	Epiphyte	Gamu	ant plants	Native			MI03-002-T3-1
Dischidia nummularlia	Asclepiadaceae	Epiphyte		ant plants	Native			MI04-001-9
Eucalyptus alba	Mytraceae	Tree	Bubu		Native			
Ficus sp	Moraceae	Tree	Kwai woo boco				✓	P002-1
Gliricidia sepum	Fabaceae	Tree	Dum loi	Gamal, Kehiri				TP03-002-11
Gmelina arborea	Lamiaceae	Tree			Native			MI03-002-T3
Grewia sp (oxyphylla?)	Malvaceae	Shrub						MI03-003-13
Hibiscus hirtus	Malvaceae	Tree			Native			TP01-001-10
Hyptis suaveolens	Lamiaceae	Herb		Horehound	Introduced/weed			
Imperata cylindrica	Poaceae	Grass						MI04-

								002-11
Indigofera linifolia	Fabaceae	Herb	Mau lame	Indigo		Least Concern		MI02-001; TP03-001-11
Indigofera sp	Fabaceae	Herb		Indigo				MI03-001
Intsia bijuga	Fabaceae	Tree	ai besi	Borneo Teak		Vulnerable	✓	P002-3
Iseilema minutiflorum	Poaceae	Grass	duut					
Jatropha gossypifolia	Euphorbiaceae	Herb		bellyache bush	Introduced/weed		Alien	
Justicia procumbens	Acanthaceae	Herb						MI04-002-13
Lantana camara (red variety)	Verbenaceae	Shrub			Introduced/weed		Alien	MI01-001
Miliusa sp	Annonaceae	Tree	Lesi a bou					TP01-001-8
Muntingia calabura	Eleocarpaceae	Tree	Ai futuk					P002-4
Neoalsomitra podoagrica	Cucurbitaceae	Herb			poss Native		✓	
Pandanus sp	Pandanaceae	Tree						
Peltophorum pterocarpum	Caesalpiniaceae	Tree	Kai kui heiu		Native			
Persea americana	Lauraceae	Tree						
Phyllanthus virgatus	Euphorbiaceae	Herb						MI04-002-12
Pithecellobium dulce	Fabaceae	Climber	Ai tarak					MI01-002-11
Pometia pinnata	Sapindaceae	Tree	Ai lele vaca		Native		✓	J001-T3; TP01-005-6
Pterocarpus indicus	Fabaceae	Tree	Kai naar	rosewood		Vulnerable	✓	TP01-002-TP03-002
Santalum album	Santalaceae	Tree	Ai kameli	sandalwood	Native	Vulnerable	✓	MI03-001-MI04-001
Schleichera oleosa	Sapindaceae	Tree	Ai dak	ceylon oak				MI01-002
Senna occidentalis	Caesalpiniaceae	Herb		sicklepod	Introduced/weed			
Senna siamea	Caesalpiniaceae	Tree						MI03-003 T1; MI03-003-7
Senna surattensis	Caesalpiniaceae	Tree	Kai saiuro					TP03-002-6
Senna timoriensis	Caesalpiniaceae	Tree						
Sesbania grandiflora	Fabaceae	Tree	Kai modok klela					TP03-002-3
Streblus asper	Moraceae	Tree			Native			P002-6
Syzigium nervosum	Mytraceae	Tree			Native			MI04-003-3
Tamarindus indica	Fabaceae	Tree						
Tecoma stans	Bignoniaceae	Shrub	Ai funan kinur	Yellow bells	Introduced/weed			MI04-001-T2
Tectona grandis	Verbenaceae	Tree	Kai bu teca	Teak				TP03-002-2
Terminalia catappa	Combretaceae	Tree		Indian, sea almond				
Thecanthes concreta	Thymelaeaceae	Herb			Native			TP03-001-12
Timonius timon	Rubiaceae	Small tree			Native			

Uraria lagopoides	Fabaceae	Herb						MI04-001
Vanda isignis	Orchidaceae	Epiphyte			Native			
Wrightia pubescens	Apocynaceae	Tree	Ai dak					MI04-001-1
Ziziphus mauritiana	Rhamnaceae	Tree		Chinee apple	Introduced/weed		Alien	
Ziziphus oenopolia	Rhamnaceae	Tree	Kai kuri; Kai ou bou					P002-5; P002-7; TP01-001-03
Ziziphus timoriensis	Rhamnaceae	Tree	Ai mutin; Kai rau di					MI04-001-6; POO2-5; TP01-001-5-5; TP01-001-6

Appendix 3. Likelihood of IUCN threatened plants and fauna species to occur at sites

IUCN Status: DD= Data deficient (A taxon with inadequate information to make a direct, or indirect, assessment of its risk of extinction based on its distribution and/or population status); NT= Near threatened ("may be considered threatened with extinction in the near future, although it does not currently qualify for the threatened status"); VU= Vulnerable ("likely to become endangered unless the circumstances threatening its survival and reproduction improve"); EN= Endangered (facing a very high risk of extinction in the wild); CR= Critically endangered (facing an extremely high risk of extinction in the wild).

Common name	IUCN	Forest specialised	Threats	Jetty	Plant	Mine	Clay mine
Plants/Trees							
Sandalwood *Santalum album*	VU	F	Habitat loss, fires, agriculture, extraction	Unlikely	Likely	**Recorded**	Likely
Borneo Teak *Intsia bijuga*	VU	F	Habitat loss/selective logging	Possible	Possible	Possible	**Recorded**
Rosewood *Pterocarpus indicus*	VU	F	Habitat loss, agriculture, selective logging	Possible	Possible	Possible	**Recorded**
Reptiles							
Roti Island Snake-necked Turtle *Chelodina maccordi*	CR		Lake Iralalaro catchment only; Hunting, habitat disturbance	Absent	Absent	Absent	Absent
Green Turtle *Chelonia mydas*	CR		Hunting, beach disturbance/conversion	Possible	Absent	Absent	Absent
Hawksbill Turtle *Eretmochelys imbricata*	CR		Hunting, beach disturbance/conversion	Possible	Absent	Absent	Absent
Leatherback Turtle *Dermochelys coriacea*	CR		Hunting, beach disturbance/conversion	Possible	Absent	Absent	Absent
Loggerhead Turtle *Caretta caretta*	EN		Hunting, beach disturbance/conversion	Possible	Absent	Absent	Absent
Olive Ridley Turtle *Lepidochelys olivacea*	EN		Hunting, beach disturbance/conversion	Possible	Absent	Absent	Absent
Mammals							
Thin Shrew *Crocidura tenuis*	VU	?	Habitat loss, degradation, restricted range	Unlikely	Possible	Possible	Possible
Western Naked-backed bat *Dobsonia peronii*	VU	F	Habitat loss, extraction, restricted range	Possible	Possible	Possible	Possible
Timor leaf-nosed bat *Hipposideros cruminiferous*	DD	F	?	Possible	Possible	Possible	Possible
Sumban Leaf-nosed Bat Hipposideros sumbae	NT	F	?	Possible	Possible	Possible	Possible

Canut's Horseshoe Bat *Rhinolophus canuti*	NT	F	?cave disturbance	**Recorded**	Likely	**Recorded**	**Recorded**
Kai Horseshoe Bat *Rhinolophus celebensis*	DD	?	?cave disturbance	**Recorded**	Likely	Likely	**Recorded**
Indonesian Tomb Bat *Taphozous achates*	DD	F	?cave disturbance	Possible	Possible	Possible	Possible
Timor Rat *Rattus timorensis*	DD	F	Montane species only	Absent	Absent	Absent	Absent
Birds							
Christmas Island Frigatebird *Fregata andrewsi*	CR		Vagrant coastal seabird	Unlikely	Absent	Absent	Absent
Malaysian Plover *Charadrius peronii*	NT		Resident beach dweller; Loss beach habitat	Likely	Absent	Absent	Absent
Black-tailed Godwit *Limosa limosa*	NT		Coastal conversion/habitat loss	Possible	Absent	Absent	Absent
Asian Dowitcher *Limnodromus semipalmatus*	NT		Coastal conversion/habitat loss	Unlikely	Absent	Absent	Absent
Beach Thick-knee *Esacus neglectus*	NT		Loss beach habitat	Likely	Absent	Absent	Absent
Timor Green Pigeon *Treron psittaceus*	EN	F	Habitat loss, hunting, agriculture	Possible	Possible	Possible	Likely
Pink-headed Imperial Pigeon *Ducula rosacea*	NT	F	Hunting, Forest loss	Likely	Likely	Likely	**Recorded**
Timor Imperial Pigeon *Ducula cineracea*	EN	F	Montane (>400 m), Habitat loss, hunting, agriculture	Absent	Absent	Absent	Possible
Slaty Cuckoo-dove *Turacoena modesta*	NT	F		Likely	Likely	Likely	Likely
Wetar Ground-dove *Gallicolumba hoedtii*	EN	F	Highly restricted; Habitat loss, hunting, agriculture	Unlikely	Unlikely	Unlikely	Unlikely
Iris Lorikeet *Psitteuteles iris*	NT	F	Forest conversion	Likely	Likely	Likely	Likely
Yellow-crested Cockatoo *Cacatua sulphurea*	CR	F	Populations destroyed by trade; Habitat loss, agriculture	Unlikely	Unlikely	Unlikely	Unlikely
Olive-shouldered Parrot *Aprosmictus jonquillaceus*	NT	F	Habitat loss, hunting, agriculture	Likely	Likely	**Recorded**	**Recorded**
Cinnamon-banded Kingfisher *Todiramphus australasia*	NT	F	Habitat loss, hunting, agriculture	Likely	Likely	**Recorded**	**Recorded**
White-bellied Bush-chat *Saxicola gutturalis*	NT	F	Loss of tropical dry forest, savanna	Possible	**Recorded**	**Recorded**	**Recorded**
Chestnut-backed Thrush *Geokichla dohertyi*	NT	F	Mostly montane; Trade (Indonesia)	Unlikely	Unlikely	Unlikely	Unlikely
Orange-banded Thrush *Geokichla peronii*	NT	F	Trade (Indonesia)	Likely	Likely	**Recorded**	**Recorded**
Black-banded Flycatcher *Ficedula timorensis*	NT	F	Tropical forest species'; Forest habitat loss	Unlikely	Unlikely	Unlikely	Likely
Spot-breasted Dark-eye *Heleia muelleri*	NT	F	Forest habitat loss	Possible	Possible	Likely	Likely
Timor Sparrow *Padda fuscata*	NT		Trade (Indonesia)	Likely	**Recorded**	**Recorded**	**Recorded**

Appendix 4. Fauna species list by study site.

Status: E= endemic; rr= globally restricted-range; F= forest specialized. IUCN [status]: ne= not yet evaluated; lc= least concern ["evaluated but not qualified for any other category. As such they do not qualify as threatened, near-threatened"); DD= Data deficient (A taxon with inadequate information to make a direct, or indirect, assessment of its risk of extinction based on its distribution and/or population status); NT= Near threatened ("may be considered threatened with extinction in the near future, although it does not currently qualify for the threatened status"); VU= Vulnerable ("likely to become endangered unless the circumstances threatening its survival and reproduction improve"). Interim List of protected species: see www.laohamutuk.org/Agri/EnvLaw/div/SpeciesLists.pdf. Species listed as present in square brackets [] were not directly recorded, but were indicated as present in site by local assistants.

English name	Scientific name	Status	IUCN	Interim list of protected species	Jetty	Plant	Mine	Clay
Amphibians								
Black-spined Toad	*Duttaphrynus melanostictus*	*Tramp/Introduced*	lc	X-Alien			X	X
Rice Paddy Frog	*Fejervarya* sp 1 [c.f. Kaiser *et al*. 2011]	Native	lc					X
Lizards								
Gekkonidae								
Tokay Gecko	*Gekko gecko*	*Tramp/Introduced*	lc	X-Trade	X	X	X	X
House Gecko	*Hemidactylus frenatus*	*Tramp/Introduced*	lc		X	X	X	X
Varanidae								
Timor Monitor	*Varanus timorensis*	Native	lc					X
Scincidae								
Skink sp.	*Carlia sp 'lowland'*	Native	ne		X			
Skink sp.	*Carlia sp 'Baucau'*	Native	ne			X	X	X
Leschenault's snake-eyed skink	*Cryptoblepharus schlegelianus*	Native	lc					X
Snakes								
Timor Inornate Bronzeback	*Dendrelaphis inornatus*	Native	lc		X			
White-lipped Island Viper	*Trimeresurus insularis*	Native	lc				X	
Mammals								
Phalangeridae								
Common Spotted Cuscus	*Phalanger orientalis*	*Introduced*	lc				[X]	[X]
Pteropodidae								
Indonesian Short-nosed Fruit Bat	*Cynopterus titthaecheilus*	Native	lc		X			
Microchiroptera								
20 cFM	*n.a*	Native			x			X
25 sFM	*n.a*	Native			x			
25 cFM	*n.a*	Native					X	X

English name	Scientific name	Status	IUCN	Interim list of protected species	Jetty	Plant	Mine	Clay
35 cFM	*n.a*	Native			X			X
45 st.cFM	*n.a*	Native			X		X	X
54 st.cFM	*n.a*	Native			X		X	X
63 st.cFM *Miniopteris australis*	*Miniopteris australis*	Native		X	X		X	X
55 mCF *Hipposideros diadema*	*Hipposideros diadema*	Native		X	X			X
72 ICF *Rhinolophis canuti*	*Rhinolophis canuti*	Native	VU	X	X		X	X
86 ICF *Rhinolophis celebensis*	*Rhinolophis celebensis*	Native	DD	X	X			X
Cercopithecidae								
Long-tailed Macaque	*Macaca fascicularis*	Native	lc			[X]	[X]	[X]
Viverridae								
Common palm civet	*Paradoxurus hermaphroditus*	*Introduced*	lc			[X]	[X]	[X]
Suidae								
Sulawesi wild boar/Feral pig	*Sus celebensis/scrofa*	*Introduced*	lc				[X]	[X]
Cervidae								
Timor/Rusa deer	*Cervus timorensis*	*Introduced*	lc				[X]	X
Bovidae								
Banteng (Bali cattle)	*Bos javanicus*	*Domesticated*	lc				X	X
Water buffalo	*Bubalis bubalis*	*Domesticated*	lc				X	X
Domestic goat	*Capra hircus*	*Domesticated*	lc		X		X	X
Domestic sheep	*Ovis aries*	*Domesticated*	lc			X	X	X
Horse	*Equus ferus caballas*	*Domesticated*	lc			X	X	X
Birds								
Spotted Kestrel	*Falco moluccensis*		lc	X			X	
Brown Quail	*Coturnix ypsilophora*		lc					X
Red Junglefowl	*Gallus gallus*		lc				X	X
Spotted Dove	*Spilopelia chinensis*		lc		X		X	X
Pacific Emerald Dove	*Chalcophaps longirostris*		lc		X		X	X
Barred Dove	*Geopelia maugeus*		lc			X	X	X
Banded Fruit Dove	*Ptilinopus cinctus*	F	lc	X			X	X
Rose-crowned Fruit Dove	*Ptilinopus regina*	F	lc	X			X	X
Pink-headed Imperial Pigeon	*Ducula rosacea*	rr,F	NT	X				X
Marigold Lorikeet	*Trichoglossus capistratus*	rr, F	lc	X				X
Olive-shouldered Parrot	*Aprosmictus jonquillaceus*	rr,F	NT	X			X	X
Little Bronze Cuckoo	*Chrysococcyx minutillus*		lc				X	X
Lesser Coucal	*Centropus bengalensis*		lc				X	
Streaked Boobook	*Ninox fusca*	E,rr,F	lc	X			X	X
Glossy Swiftlet	*Collocalia esculenta*		lc	X	X	X	X	X
Collared Kingfisher	*Todiramphus chloris*		lc				X	X
Cinnamon-banded Kingfisher	*Todiramphus australasia*	rr,F	NT	X		X	X	X
Rainbow Bee-eater	*Merops ornatus*	migrant	lc				X	X
Paddyfield Pipit	*Anthus rufulus*		lc				X	X

English name	Scientific name	Status	IUCN	Interim list of protected species	Jetty	Plant	Mine	Clay
Wallacean Cuckooshrike	*Coracina personata*	F	lc				X	X
White-shouldered Triller	*Lalage sueurii*		lc				X	X
Wallacean Drongo	*Dicrurus densus*	F	lc	X				X
Timor Oriole	*Oriolus melanotis*	rr,F	lc	X			X	X
Timor Figbird	*Sphecotheres viridis*	E,rr,F	lc	X			X	X
Large-billed Crow	*Corvus macrorhynchos*		lc		X			
Orange-sided Thrush	*Geokichla peronii*	rr,F	NT	X			X	X
Pied Bush Chat	*Saxicola caprata*		lc				X	X
White-bellied Bush Chat	*Saxicola gutturalis*	E,rr,F	NT	X			X	X
Plain Gerygone	*Gerygone inornata*	rr	lc	X		X	X	X
Timor Stubtail	*Urosphena subulata*	rr,F	lc	X				X
Buff-banded Thicketbird	*Buettikoferella bivittata*	E,rr,F	lc	X				X
Little Pied Flycatcher	*Ficedula westermanni*	F	lc			X		X
Timor Blue Flycatcher	*Cyornis hyacinthinus*	rr,F	lc	X				X
Spectacled Monarch	*Symposiachrus trivirgatus*	F	lc					X
Broad-billed Flycatcher	*Myiagra ruficollis*		lc					X
Northern Fantail	*Rhipidura rufiventris*	F	lc		X	X	X	X
Arafura Fantail	*Rhipidura dryas*	F	lc					X
Fawn-breasted Whistler	*Pachycephala orpheus*	rr,F	lc	X			X	X
Yellow-throated Whistler	*Pachycephala macrorhyncha*	rr,F	lc	X				X
White-breasted Woodswallow	*Artamus leucorynchus*		lc				X	X
Long-tailed Shrike	*Lanius schach*		lc				X	
Timor Friarbird	*Philemon inornatus*	E,rr,F	lc	X	X	X	X	X
Helmeted Friarbird	*Philemon buceroides*	F	lc	X		X	X	X
Streak-breasted Honeyeater	*Meliphaga reticulata*	E,rr	lc	X	X	X	X	X
Indonesian Honeyeater	*Lichmera limbata*		lc		X	X	X	X
Black-breasted Myzomela	*Myzomela vulnerata*	E,rr	lc	X				X
Flame-breasted Sunbird	*Cinnyris solaris*	rr	lc	X				X
Blue-cheeked Flowerpecker	*Dicaeum maugei*	rr	lc			X	X	X
Ashy-bellied White-eye	*Zosterops citrinella*	F	lc			X		X
Red Avadavat	*Amandava amandava*		lc				X	X
Zebra Finch	*Taeniopygia guttata*		lc			X	X	X
Tricolored Parrotfinch	*Erythrura tricolor*	rr,F	lc	X				X
Scaly-breasted Munia	*Lonchura punctulata*		lc				X	X
Five-colored Munia	*Lonchura quinticolor*		lc				X	X
Pale-headed Munia	*Lonchura pallida*		lc				X	X
Timor Sparrow	*Lonchura fuscata*	E,rr	NT	X		X	X	X

Appendix 5. Presence of fauna species at 24 point count fauna survey sites.

Scientific name	English name	Jetty 01	Jetty02	Plant01	Plant02	Plant03	Mine01	Mine02	Mine03	Mine04	Mine05	Mine06	Mine07	Mine08	Mine09	Mine10	Clay01	Clay02	Clay03	Clay04	Clay05	Clay06	Clay07	Clay08	Clay09
Amphibians																									
Bufo/Duttaphrynus melanostictus	Black-spined Toad																X								
Fejervarya sp 1 [c.f. Kaiser *et al.* 2011]	Rice Paddy Frog																								
Lizards																									
Gekkonidae																									
Gekko gecko	Tokay Gecko	X			X										X	X	X		X		X		X		X
Hemidactylus frenatus	House Gecko	X		X									X				X	X							
Varanidae																									
Varanus timorensis	Timor Monitor																								
Scincidae																									
Carlia sp 'lowland'	Skink sp.					X								X	X	X									
Carlia sp 2 'Baucau'	Skink sp.	X											X		X										
Cryptoblepharus schlegelianus	Leschenault's snake-eyed skink																								
Snakes																									
Dendrelaphis inornatus timorensis	Timor Inornate Bronzeback																								
Trimeresurus insularis	White-lipped Island Viper																								
Mammals																									
Phalangeridae																									
Phalanger orientalis	Common Spotted Cuscus																								

Pteropodidae																									
Cynopterus titthaecheilus	Indonesian Short-nosed Fruit Bat																								
Cercopithecidae																									
Macaca fascicularis	Long-tailed Macaque																								
Viverridae																									
Paradoxurus hermaphroditus	Common palm civet																								
Suidae																									
Sus celebensis	Sulawesi wild boar/warty pig																								
Cervidae																									
Cervus timorensis	Timor/Rusa deer									X															
Bovidae																									
Bos javanicus	Banteng (Bali cattle)																								
Bubalis bubalis	Water buffalo																								
Capra hircus	Domestic goat	X	X																						
Ovis aries	Domestic sheep			X																					
Equus ferus caballas	Horse				X											X									
Birds																									
Spotted Kestrel	*Falco moluccensis*																								
Brown Quail	*Coturnix ypsilophora*																								
Red Junglefowl	*Gallus gallus*												X					X		X		X	X		
Spotted Dove	*Spilopelia chinensis*	X						X																	
Pacific Emerald Dove	*Chalcophaps longirostris*																						X		
Barred Dove	*Geopelia maugeus*			X	X		X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X		X
Banded Fruit Dove	*Ptilinopus cinctus*																X			X			X		
Rose-crowned Fruit Dove	*Ptilinopus regina*								X		X					X		X	X	X	X				
Pink-headed Imperial Pigeon	*Ducula rosacea*																		X						
Marigold Lorikeet	*Trichoglossus capistratus*																					X			
Olive-shouldered Parrot	*Aprosmictus jonquillaceus*												X	X						X	X				

Little Bronze Cuckoo	*Chrysococcyx minutillus*																	X		X				X	
Lesser Coucal	*Centropus bengalensis*								X																
Streaked Boobook	*Ninox fusca*																								
Glossy Swiftlet	*Collocalia esculenta*					X		X	X	X					X	X				X	X	X			
Collared Kingfisher	*Todiramphus chloris*							X																X	
Cinnamon-banded Kingfisher	*Todiramphus australasia*			X															X		X		X		
Rainbow Bee-eater	*Merops ornatus*							X		X				X	X		X	X	X	X		X			X
Paddyfield Pipit	*Anthus rufulus*												X								X				
Wallacean Cuckooshrike	*Coracina personata*												X		X		X								
White-shouldered Triller	*Lalage sueurii*						X				X		X					X				X			X
Wallacean Drongo	*Dicrurus densus*																X			X				X	
Timor Oriole	*Oriolus melanotis*						X			X									X	X			X	X	X
Timor Figbird	*Sphecotheres viridis*						X		X					X		X	X	X	X	X		X	X		
Large-billed Crow	*Corvus macrorhynchos*																								
Orange-sided Thrush	*Geokichla peronii*																X		X						
Pied Bush Chat	*Saxicola caprata*							X					X	X											X
White-bellied Bush Chat	*Saxicola gutturalis*						X	X	X		X		X	X		X	X	X	X	X	X	X	X		
Plain Gerygone	*Gerygone inornata*				X		X		X		X		X	X	X	X	X	X	X	X	X	X	X		
Timor Stubtail	*Urosphena subulata*																X		X					X	
Buff-banded Thicketbird	*Buettikoferella bivittata*																X	X	X				X		
Little Pied Flycatcher	*Ficedula westermanni*			X	X													X							
Timor Blue Flycatcher	*Cyornis hyacinthinus*																	X							
Spectacled Monarch	*Symposiachrus trivirgatus*																		X				X	X	
Broad-billed Flycatcher	*Myiagra ruficollis*																X				X				
Northern Fantail	*Rhipidura rufiventris*				X		X	X		X		X				X	X	X	X	X	X				
Arafura Fantail	*Rhipidura dryas*																				X				
Fawn-breasted Whistler	*Pachycephala orpheus*						X	X	X	X				X	X	X	X	X	X	X	X	X	X	X	
Yellow-throated Whistler	*Pachycephala macrorhyncha*																		X						
White-breasted Woodswallow	*Artamus leucorynchus*						X										X								X

Black-faced Woodswallow	*Artamus cinereus*																								
Long-tailed Shrike	*Lanius schach*												X	X											
Timor Friarbird	*Philemon inornatus*			X			X	X	X		X			X	X		X	X	X				X	X	X
Helmeted Friarbird	*Philemon buceroides*				X		X	X	X										X			X	X		
Streak-breasted Honeyeater	*Meliphaga reticulata*		X	X			X	X	X	X	X		X	X	X	X	X	X	X	X		X	X	X	
Indonesian Honeyeater	*Lichmera limbata*						X		X							X									
Black-breasted Myzomela	*Myzomela vulnerata*													X			X							X	
Flame-breasted Sunbird	*Cinnyris solaris*																X	X					X	X	
Blue-cheeked Flowerpecker	*Dicaeum maugei*			X		X	X	X	X	X		X	X	X	X	X		X	X		X	X	X	X	X
Ashy-bellied White-eye	*Zosterops citrinella*			X													X	X	X	X	X	X			
Red Avadavat	*Amandava amandava*							X																	X
Zebra Finch	*Taeniopygia guttata*			X				X						X	X	X	X	X	X	X	X	X			X
Tricolored Parrotfinch	*Erythrura tricolor*																	X					X		
Scaly-breasted Munia	*Lonchura punctulata*										X														
Five-colored Munia	*Lonchura quinticolor*													X					X				X		
Pale-headed Munia	*Lonchura pallida*							X	X	X															X
Timor Sparrow	*Lonchura fuscata*									X			X		X										

Appendix 6. Fauna habitat characteristics for each of 24 point count fauna survey sites.

Fauna Habitat Assessment:

Site Name: Mine 1

Date: **21/5/2015**

UTM Coordinates: 52 209264 Easting, 906 3205 Northing

Elevation (m): 261 m

Habitat value: Moderate

Vegetation Type: Closed Tropical Forest (secondary)

Canopy Cover: 60%

Canopy Height: 10 m

Disturbance:

Fire Impact (0-5): 0

Cow/horse/Buffalo(0-5): 0

Weeds (0-5): 1

Total: 1

Rock cover:

Stones 2-6cm (%): 5

Rocks 6-20cm (%): 10

Rocks 20-60cm (%): 10

Big rocks 60-200 cm (%): 5

Rock Outcrop (%): 0

Ground cover:

Bare ground (%): 0

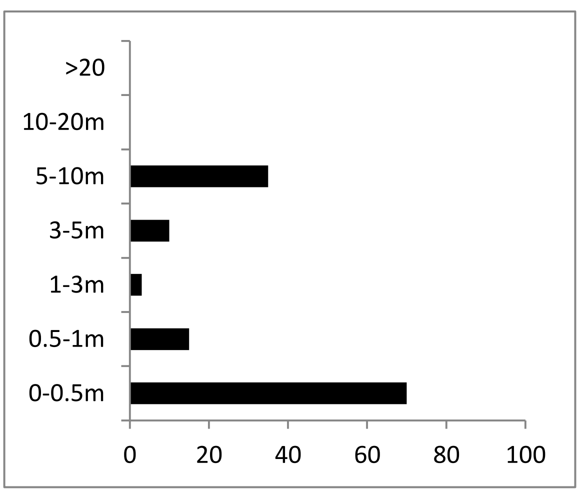
Leaf litter (%): 70

Grass (%): 0

Palm cover (%): 0

Log number: 2

Vegetation Profile, % cover in different height classes:



Fauna Habitat Assessment:

Site Name: Mine 2

Date: **21/5/2015**

UTM Coordinates: 52 209457 Easting, 906 3192 Northing

Elevation (m): 270 m

Habitat value: Moderate

Vegetation Type: *Eucalyptus alba* woodland

Canopy Cover: 10%

Canopy Height: 7 m

Disturbance:

Fire Impact (0-5): 0

Cow/horse/Buffalo(0-5): 2

Weeds (0-5): 3

Total: 5 (High)

Rock cover:

Stones 2-6cm (%): 5

Rocks 6-20cm (%): 5

Rocks 20-60cm (%): 10

Big rocks 60-200 cm (%): 10

Rock Outcrop (%): 20

Ground cover:

Bare ground (%): 0

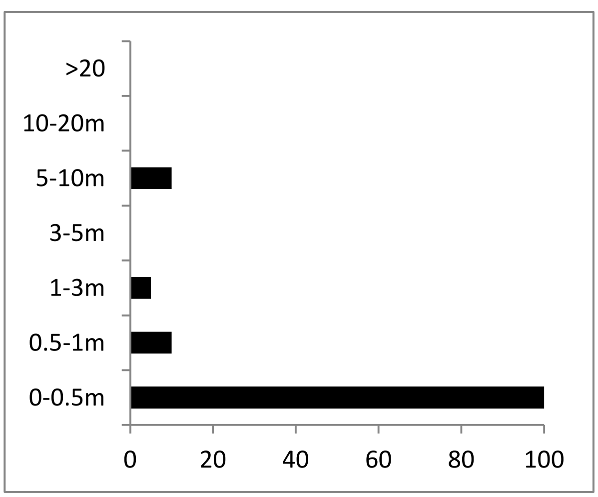
Leaf litter (%): 30

Grass (%): 50

Palm cover (%): 0

Log number: 0

Vegetation Profile, % cover in different height classes:



Fauna Habitat Assessment:

Site Name: Mine 3

Date: **21/5/2015**

UTM Coordinates: 52 209151 Easting, 906 3156 Northing

Elevation (m): 270 m

Habitat value: Moderate

Vegetation Type: *Schleichera oleosa* woodland

Canopy Cover: 20%

Canopy Height: 8 m

Disturbance:

Fire Impact (0-5): 0

Cow/horse/Buffalo(0-5): 0

Weeds (0-5): 3

Total: 3 (Moderate)

Rock cover:

Stones 2-6cm (%): 0

Rocks 6-20cm (%): 10

Rocks 20-60cm (%): 10

Big rocks 60-200 cm (%): 0

Rock Outcrop (%): 0

Ground cover:

Bare ground (%): 0

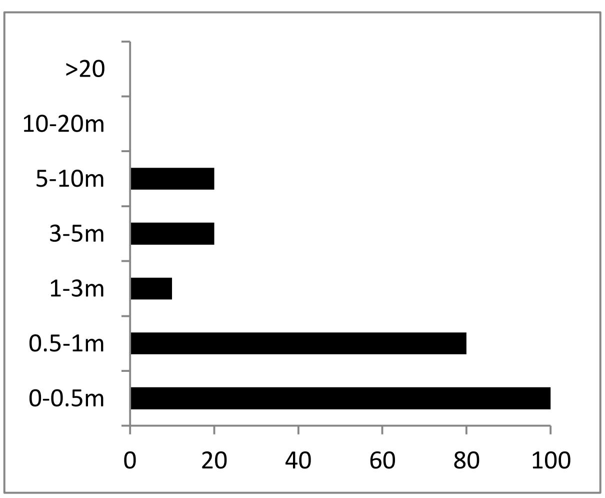
Leaf litter (%): 20

Grass (%): 10

Palm cover (%): 0

Log number: 0

Vegetation Profile, % cover in different height classes:



Fauna Habitat Assessment:

Site Name: Mine 4

Date: **21/5/2015**

UTM Coordinates: 52 208890 Easting, 906 3040 Northing

Elevation (m): 244 m

Habitat value: Moderate

Vegetation Type: *Schleichera oleosa* woodland (old garden)

Canopy Cover: 15%

Canopy Height: 8 m

Disturbance:

Fire Impact (0-5): 0

Agriculture (0-5): 2

Cow/horse/Buffalo (0-5): 2

Weeds (0-5): 3

Total: 7 (High)

Rock cover:

Stones 2-6cm (%): 0

Rocks 6-20cm (%): 10

Rocks 20-60cm (%): 10

Big rocks 60-200 cm (%): 0

Rock Outcrop (%): 0

Ground cover:

Bare ground (%): 0

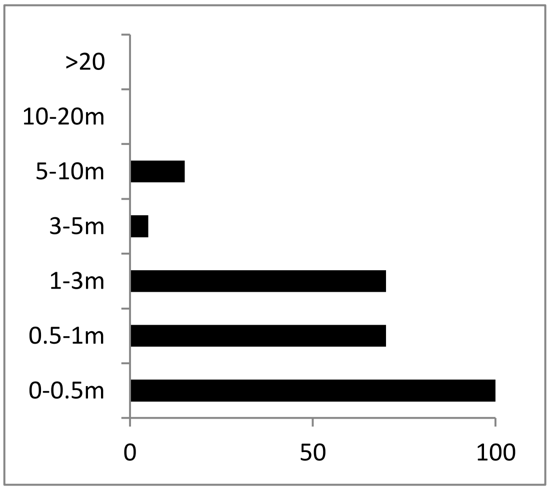
Leaf litter (%): 30

Grass (%): 10

Palm cover (%): 0

Log number: 0

Vegetation Profile, % cover in different height classes:



Fauna Habitat Assessment:

Site Name: Mine 5

Date: 21/5/2015

UTM Coordinates: 52 208599 Easting, 906 2910 Northing

Elevation (m): 247 m

Habitat value: Low

Vegetation Type: *Schleichera oleosa* woodland (old garden)

Canopy Cover: 40%

Canopy Height: 9 m

Disturbance:

Fire Impact (0-5): 0

Agriculture (0-5): 2

Cow/horse/Buffalo (0-5): 0

Weeds (0-5): 3

Total: 5 (High)

Rock cover:

Stones 2-6cm (%): 0

Rocks 6-20cm (%): 10

Rocks 20-60cm (%): 20

Big rocks 60-200 cm (%): 50

Rock Outcrop (%): 0

Ground cover:

Bare ground (%): 0

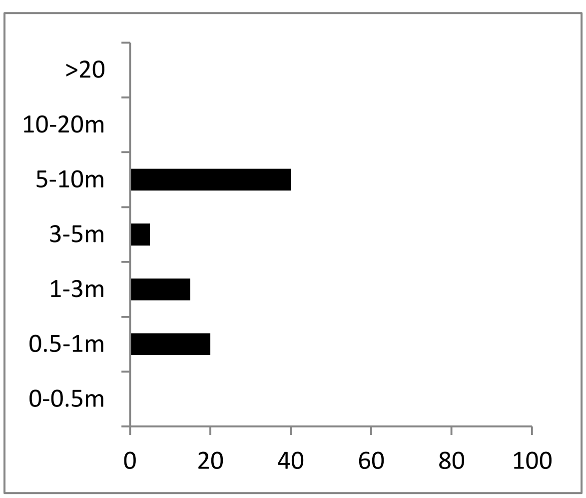
Leaf litter (%): 50

Grass (%): 10

Palm cover (%): 0

Log number: 0

Vegetation Profile, % cover in different height classes:



Fauna Habitat Assessment:

Site Name: Mine 6

Date: **21/5/2015**

UTM Coordinates: 52 208599 Easting, 906 2910 Northing

Elevation (m): 230 m

Habitat value: Low

Vegetation Type: *Eucalyptus alba* woodland

Canopy Cover: 14%

Canopy Height: 5 m

Disturbance:

Fire Impact (0-5): 0

Agriculture (0-5): 0

Cow/horse/Buffalo (0-5): 0

Weeds (0-5): 3

Total: 3 (High)

Rock cover:

Stones 2-6cm (%): 0

Rocks 6-20cm (%): 2

Rocks 20-60cm (%): 5

Big rocks 60-200 cm (%): 5

Rock Outcrop (%): 0

Ground cover:

Bare ground (%): 10

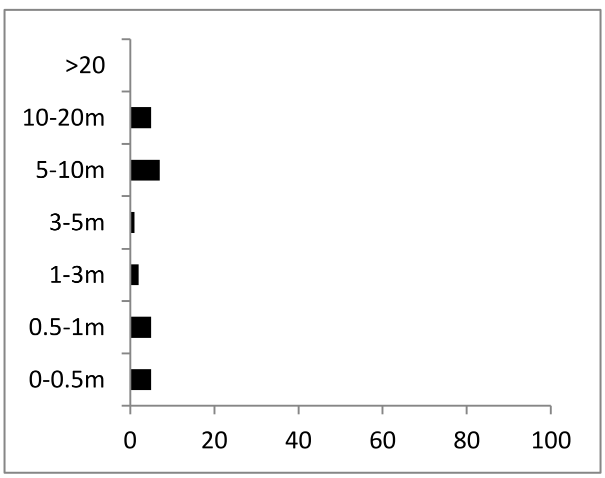
Leaf litter (%): 2

Grass (%): 5

Palm cover (%): 0

Log number: 1

Vegetation Profile, % cover in different height classes:



Fauna Habitat Assessment:

Site Name: Mine 7 [northwest test pit]

Date: **22/5/2015**

UTM Coordinates: 52 208422 Easting, 906 4205 Northing

Elevation (m): 96 m

Habitat value: Moderate

Vegetation Type: *Eucalyptus alba* woodland

Canopy Cover: 10%

Canopy Height: 12 m

Disturbance:

Fire Impact (0-5): 0

Agriculture (0-5): 0

Cow/horse/Buffalo (0-5): 1

Weeds (0-5): 3

Total: 4 (Moderate)

Rock cover:

Stones 2-6cm (%): 5

Rocks 6-20cm (%): 10

Rocks 20-60cm (%): 10

Big rocks 60-200 cm (%): 0

Rock Outcrop (%): 0

Ground cover:

Bare ground (%): 5

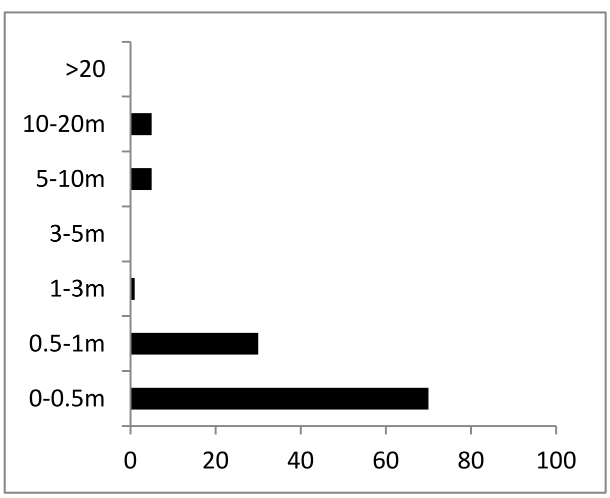
Leaf litter (%): 15

Grass (%): 5

Palm cover (%): 0

Log number: 2

Vegetation Profile, % cover in different height classes:



Fauna Habitat Assessment:

Site Name: Mine 8

Date: **22/5/2015**

UTM Coordinates: 52 208422 Easting, 906 4205 Northing

Elevation (m): 96 m

Habitat value: Moderate

Vegetation Type: *Eucalyptus alba* woodland

Canopy Cover: 10%

Canopy Height: 12 m

Disturbance:

Fire Impact (0-5): 0

Agriculture (0-5): 0

Cow/horse/Buffalo (0-5): 0

Weeds (0-5): 1

Total: 1 (Low)

Rock cover:

Stones 2-6cm (%): 0

Rocks 6-20cm (%): 25

Rocks 20-60cm (%): 20

Big rocks 60-200 cm (%): 0

Rock Outcrop (%): 0

Ground cover:

Bare ground (%): 0

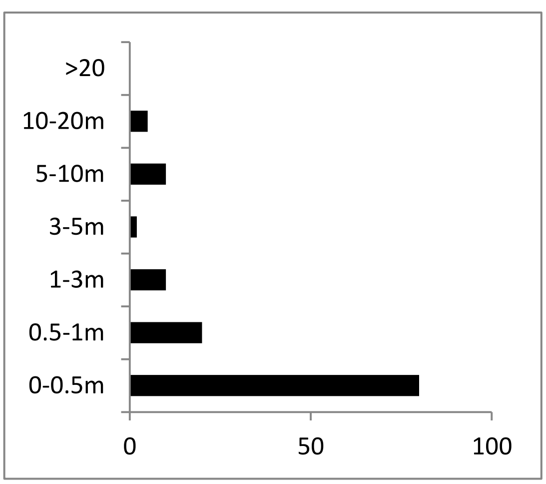
Leaf litter (%): 20

Grass (%): 50

Palm cover (%): 0

Log number: 3

Vegetation Profile, % cover in different height classes:



Fauna Habitat Assessment:

Site Name: Mine 9

Date: **22/5/2015**

UTM Coordinates: 52 208222 Easting, 906 3983 Northing

Elevation (m): 108 m

Habitat value: Moderate

Vegetation Type: *Eucalyptus alba* woodland

Canopy Cover: 10%

Canopy Height: 12 m

Disturbance:

Fire Impact (0-5): 0

Agriculture (0-5): 0

Cow/horse/Buffalo (0-5): 0

Weeds (0-5): 2

Total: 2 (Low)

Rock cover:

Stones 2-6cm (%): 0

Rocks 6-20cm (%): 10

Rocks 20-60cm (%): 10

Big rocks 60-200 cm (%): 0

Rock Outcrop (%): 0

Ground cover:

Bare ground (%): 0

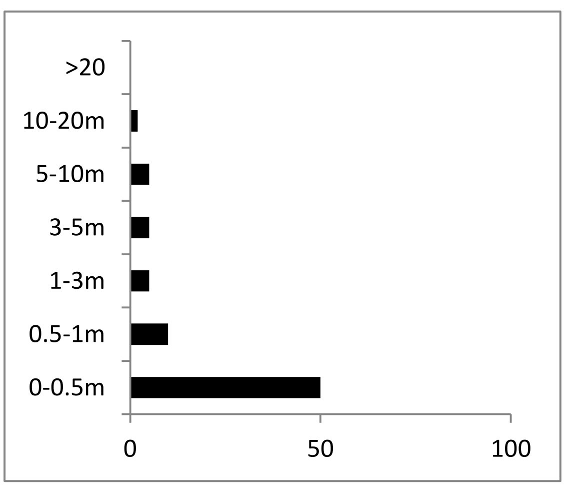
Leaf litter (%): 5

Grass (%): 15

Palm cover (%): 0

Log number: 0

Vegetation Profile, % cover in different height classes:



Fauna Habitat Assessment:

Site Name: Mine 10

Date: **22/5/2015**

UTM Coordinates: 52 207900 Easting, 906 3892 Northing

Elevation (m): 104 m

Habitat value: Moderate

Vegetation Type: *Eucalyptus alba* woodland

Canopy Cover: 10%

Canopy Height: 12 m

Disturbance:

Fire Impact (0-5): 0

Agriculture (0-5): 0

Cow/horse/Buffalo (0-5): 2

Weeds (0-5): 4

Total: 6 (High)

Rock cover:

Stones 2-6cm (%): 0

Rocks 6-20cm (%): 10

Rocks 20-60cm (%): 20

Big rocks 60-200 cm (%): 0

Rock Outcrop (%): 0

Ground cover:

Bare ground (%): 5

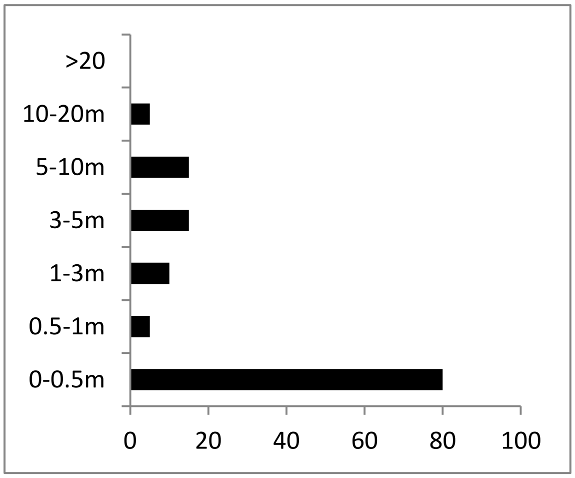
Leaf litter (%): 5

Grass (%): 0

Palm cover (%): 0

Log number: 0

Vegetation Profile, % cover in different height classes:



Fauna Habitat Assessment:

Site Name: Plant 1

Date: 22/5/2015

UTM Coordinates: 52 207857 Easting, 906 4224 Northing

Elevation (m): 65 m

Habitat value: Moderate

Vegetation Type: *Eucalyptus alba* woodland

Canopy Cover: 10%

Canopy Height: 11 m

Disturbance:

Fire Impact (0-5): 0

Agriculture (0-5): 0

Cow/horse/Buffalo (0-5): 1

Weeds (0-5): 2

Total: 3 (Moderate)

Rock cover:

Stones 2-6cm (%): 0

Rocks 6-20cm (%): 10

Rocks 20-60cm (%): 30

Big rocks 60-200 cm (%): 0

Rock Outcrop (%): 40

Ground cover:

Bare ground (%): 0

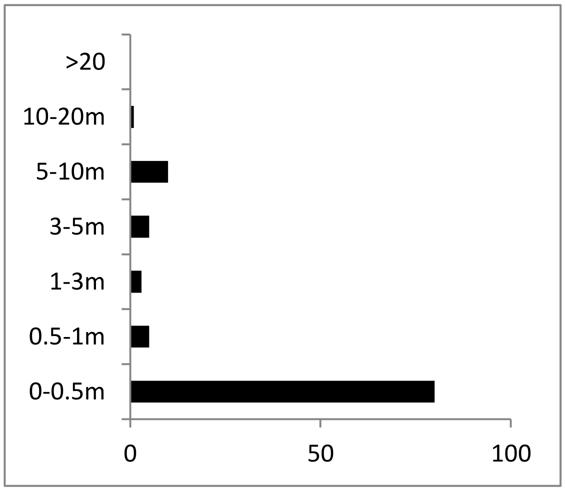
Leaf litter (%): 5

Grass (%): 30

Palm cover (%): 0

Log number: 0

Vegetation Profile, % cover in different height classes:



Fauna Habitat Assessment:

Site Name: Plant 2

Date: 22/5/2015

UTM Coordinates: 52 207861 Easting, 906 4481 Northing

Elevation (m): 49 m

Habitat value: Low

Vegetation Type: *Eucalyptus alba* woodland

Canopy Cover: 4%

Canopy Height: 11 m

Disturbance:

Fire Impact (0-5): 0

Agriculture (0-5): 0

Cow/horse/Buffalo (0-5): 3

Weeds (0-5): 3

Total: 6(High)

Rock cover:

Stones 2-6cm (%): 0

Rocks 6-20cm (%): 10

Rocks 20-60cm (%): 10

Big rocks 60-200 cm (%): 10

Rock Outcrop (%): 50

Ground cover:

Bare ground (%): 0

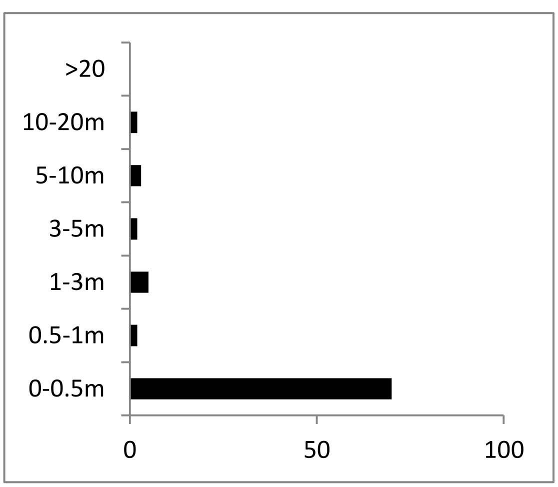
Leaf litter (%): 10

Grass (%): 50

Palm cover (%): 0

Log number: 6

Vegetation Profile, % cover in different height classes:



Fauna Habitat Assessment:

Site Name: Plant 3

Date: 22/5/2015

UTM Coordinates: 52 207861 Easting, 906 4481 Northing

Elevation (m): 49 m

Habitat value: Low

Vegetation Type: *Eucalyptus alba* woodland

Canopy Cover: 4%

Canopy Height: 11 m

Disturbance:

Fire Impact (0-5): 0

Agriculture (0-5): 0

Cow/horse/Buffalo (0-5): 3

Weeds (0-5): 3

Total: 6(High)

Rock cover:

Stones 2-6cm (%): 0

Rocks 6-20cm (%): 10

Rocks 20-60cm (%): 10

Big rocks 60-200 cm (%): 10

Rock Outcrop (%): 50

Ground cover:

Bare ground (%): 0

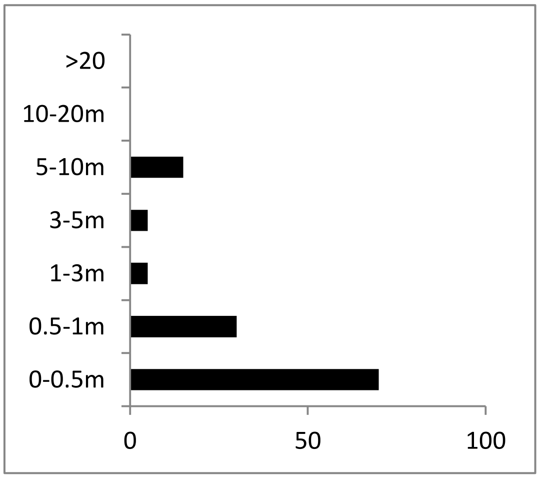
Leaf litter (%): 10

Grass (%): 50

Palm cover (%): 0

Log number: 6

Vegetation Profile, % cover in different height classes:



Fauna Habitat Assessment:

Site Name: Jetty Option 1

Date: 22/5/2015

UTM Coordinates: 52 207584 Easting, 906 5439 Northing

Elevation (m): 1 m

Habitat value: Moderate

Vegetation Type: Beach forest (degraded)

Canopy Cover: 70%

Canopy Height: 19 m

Disturbance:

Fire Impact (0-5): 0

Agriculture (0-5): 1

Cow/horse/Buffalo (0-5): 3

Weeds (0-5): 1

Total: 5 (High)

Rock cover:

Stones 2-6cm (%): 0

Rocks 6-20cm (%): 0

Rocks 20-60cm (%): 0

Big rocks 60-200 cm (%): 0

Rock Outcrop (%): 0

Ground cover:

Bare ground (%): 50

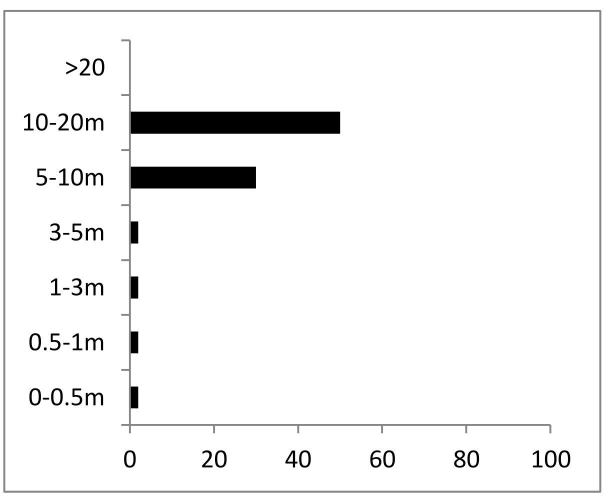
Leaf litter (%): 50

Grass (%): 0

Palm cover (%): 70

Log number: 0

Vegetation Profile, % cover in different height classes:



Fauna Habitat Assessment:

Site Name: Jetty Option 2

Date: 22/5/2015

UTM Coordinates: 52 207670 Easting, 906 5593 Northing

Elevation (m): 1 m

Habitat value: Moderate

Vegetation Type: Beach forest (degraded)

Canopy Cover: 30%

Canopy Height: 18 m

Disturbance:

Fire Impact (0-5): 3

Agriculture (0-5): 0

Cow/horse/Buffalo (0-5): 3

Weeds (0-5): 4

Total: 10 (High)

Rock cover:

Stones 2-6cm (%): 0

Rocks 6-20cm (%): 0

Rocks 20-60cm (%): 0

Big rocks 60-200 cm (%): 0

Rock Outcrop (%): 0

Ground cover:

Bare ground (%): 30

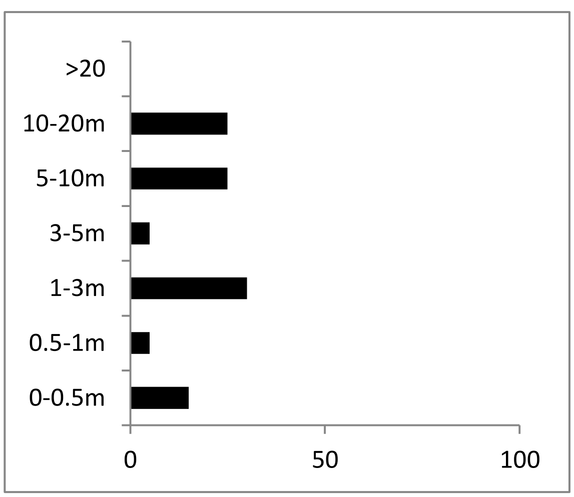
Leaf litter (%): 50

Grass (%): 0

Palm cover (%): 30

Log number: 5

Vegetation Profile, % cover in different height classes:



Fauna Habitat Assessment:

Site Name: Clay 1

Date: **23/5/2015**

UTM Coordinates: 52 203757 Easting, 905 8280 Northing

Elevation (m): 295 m

Habitat value: High

Vegetation Type: Bamboo thicket

Canopy Cover: 60%

Canopy Height: 15 m

Disturbance:

Fire Impact (0-5): 0

Cow/horse/Buffalo(0-5): 0

Weeds (0-5): 1

Total: 1

Rock cover:

Stones 2-6cm (%): 5

Rocks 6-20cm (%): 0

Rocks 20-60cm (%): 0

Big rocks 60-200 cm (%): 0

Rock Outcrop (%): 0

Ground cover:

Bare ground (%): 0

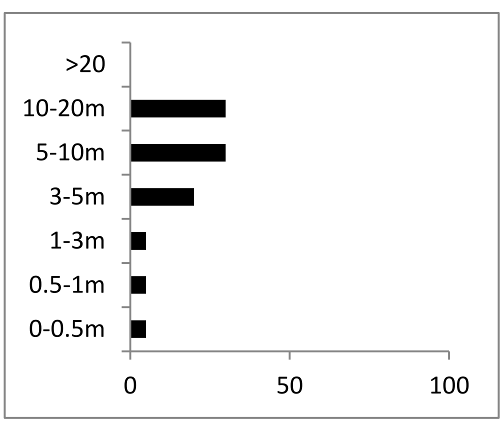
Leaf litter (%): 70

Grass (%): 70

Palm cover (%): 0

Log number: 0

Vegetation Profile, % cover in different height classes:



Fauna Habitat Assessment:

Site Name: Clay 2

Date: **23/5/2015**

UTM Coordinates: 52 202764 Easting, 905 8264 Northing

Elevation (m): 306 m

Habitat value: Moderate

Vegetation Type: Bamboo thicket

Canopy Cover: 40%

Canopy Height: 19 m

Disturbance:

Fire Impact (0-5): 0

Cow/horse/Buffalo(0-5): 1

Weeds (0-5): 2

Total: 3 (Low)

Rock cover:

Stones 2-6cm (%): 1

Rocks 6-20cm (%): 1

Rocks 20-60cm (%): 0

Big rocks 60-200 cm (%): 1

Rock Outcrop (%): 0

Ground cover:

Bare ground (%): 0

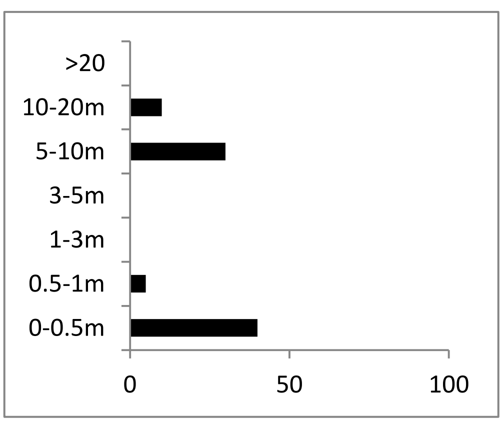
Leaf litter (%): 20

Grass (%): 40

Palm cover (%): 0

Log number: 0

Vegetation Profile, % cover in different height classes:



Fauna Habitat Assessment:

Site Name: Clay 3

Date: 24/5/2015

UTM Coordinates: 52 203133 Easting, 905 9784 Northing

Elevation (m): 146 m

Habitat value: Low

Vegetation Type: Bamboo thicket

Canopy Cover: 15%

Canopy Height: 18 m

Disturbance:

Fire Impact (0-5): 0

Cow/horse/Buffalo(0-5): 1

Weeds (0-5): 3

Total: 4 (Moderate)

Rock cover:

Stones 2-6cm (%): 5

Rocks 6-20cm (%): 5

Rocks 20-60cm (%): 0

Big rocks 60-200 cm (%): 0

Rock Outcrop (%): 0

Ground cover:

Bare ground (%): 0

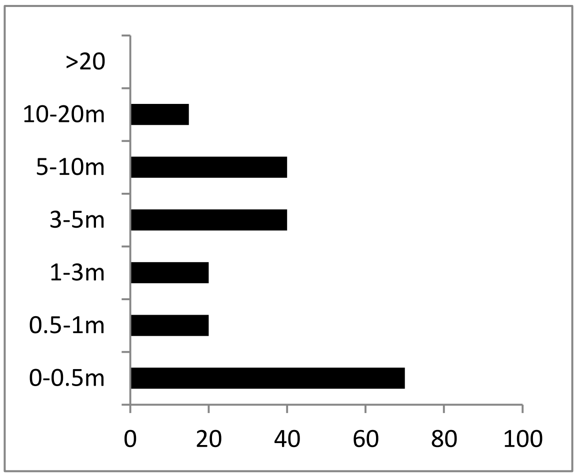
Leaf litter (%): 10

Grass (%): 20

Palm cover (%): 0

Log number: 1

Vegetation Profile, % cover in different height classes:



Fauna Habitat Assessment:

Site Name: Clay 4

Date: **24/5/2015**

UTM Coordinates: 52 202929 Easting, 905 9647 Northing

Elevation (m): 156 m

Habitat value: Low

Vegetation Type: Woodland (Acacia/grazing land)

Canopy Cover: 7%

Canopy Height: 8 m

Disturbance:

Fire Impact (0-5): 0

Cow/horse/Buffalo(0-5): 3

Weeds (0-5): 2

Total: 5 (High)

Rock cover:

Stones 2-6cm (%): 5

Rocks 6-20cm (%): 10

Rocks 20-60cm (%): 3

Big rocks 60-200 cm (%): 2

Rock Outcrop (%): 0

Ground cover:

Bare ground (%): 5

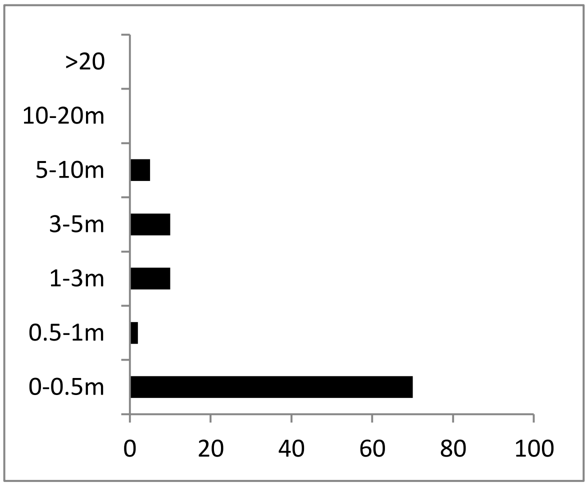
Leaf litter (%): 1

Grass (%): 80

Palm cover (%): 0

Log number: 0

Vegetation Profile, % cover in different height classes:



Fauna Habitat Assessment:

Site Name: Clay 5

Date: **24/5/2015**

UTM Coordinates: 52 202810 Easting, 905 9442 Northing

Elevation (m): 189 m

Habitat value: Low

Vegetation Type: Woodland (between closed tropical forest)

Canopy Cover: 10%

Canopy Height: 14 m

Disturbance:

Fire Impact (0-5): 0

Cow/horse/Buffalo(0-5): 1

Weeds (0-5): 1

Total: 2 (Low)

Rock cover:

Stones 2-6cm (%): 10

Rocks 6-20cm (%): 10

Rocks 20-60cm (%): 5

Big rocks 60-200 cm (%): 5

Rock Outcrop (%): 0

Ground cover:

Bare ground (%): 5

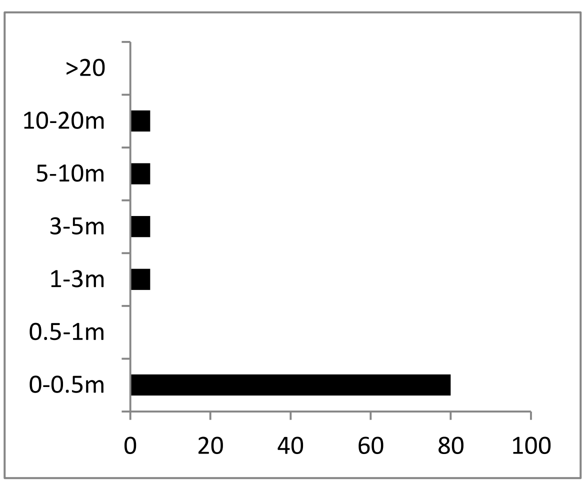
Leaf litter (%): 1

Grass (%): 70

Palm cover (%): 0

Log number: 1

Vegetation Profile, % cover in different height classes:



Fauna Habitat Assessment:

Site Name: Clay 6

Date: **24/5/2015**

UTM Coordinates: 52 202777 Easting, 905 9276 Northing

Elevation (m): 212 m

Habitat value: Low

Vegetation Type: Woodland (between closed tropical forest)

Canopy Cover: 5%

Canopy Height: 11 m

Disturbance:

Fire Impact (0-5): 0

Cow/horse/Buffalo(0-5): 3

Weeds (0-5): 2

Total: 5 (High)

Rock cover:

Stones 2-6cm (%): 0

Rocks 6-20cm (%): 30

Rocks 20-60cm (%): 20

Big rocks 60-200 cm (%): 5

Rock Outcrop (%): 0

Ground cover:

Bare ground (%): 0

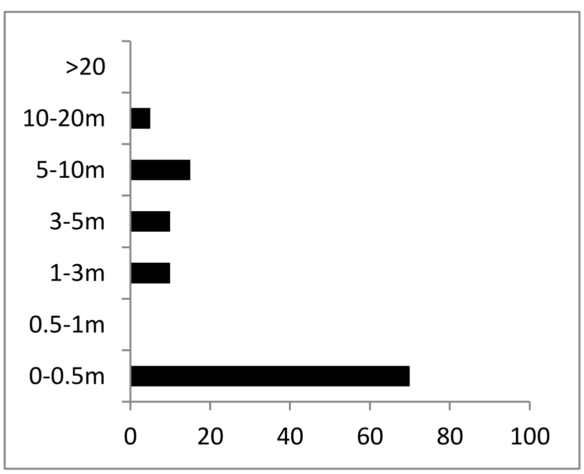
Leaf litter (%): 0

Grass (%): 80

Palm cover (%): 0

Log number: 0

Vegetation Profile, % cover in different height classes:



Fauna Habitat Assessment:

Site Name: Clay 7

Date: **24/5/2015**

UTM Coordinates: 52 202557 Easting, 905 9310 Northing

Elevation (m): 217 m

Habitat value: Moderate

Vegetation Type: Closed Tropical Forest (secondary)

Canopy Cover: 30%

Canopy Height: 13 m

Disturbance:

Fire Impact (0-5): 0

Cow/horse/Buffalo(0-5): 1

Weeds (0-5): 3

Total: 4 (High)

Rock cover:

Stones 2-6cm (%): 0

Rocks 6-20cm (%): 30

Rocks 20-60cm (%): 20

Big rocks 60-200 cm (%): 5

Rock Outcrop (%): 0

Ground cover:

Bare ground (%): 0

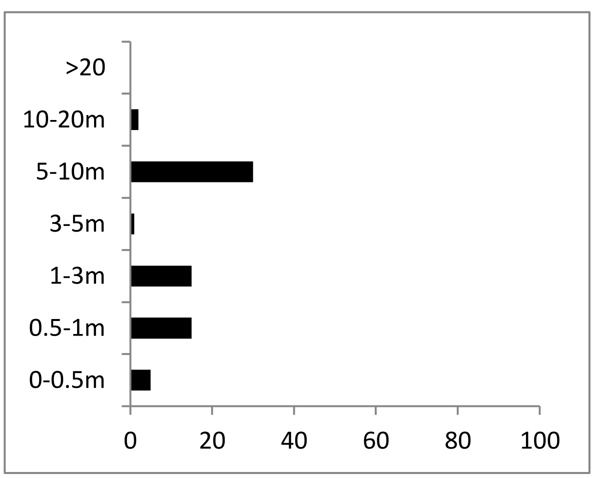
Leaf litter (%): 0

Grass (%): 80

Palm cover (%): 0

Log number: 0

Vegetation Profile, % cover in different height classes:



Fauna Habitat Assessment:

Site Name: Clay 8

Date: **25/5/2015**

UTM Coordinates: 52 204241 Easting, 905 9789 Northing

Elevation (m): 208 m

Habitat value: Moderate

Vegetation Type: Closed Tropical Forest (riparian/bamboo)

Canopy Cover: 35%

Canopy Height: 22 m

Disturbance:

Fire Impact (0-5): 0

Cow/horse/Buffalo(0-5): 3

Weeds (0-5): 3

Total: 6 (High)

Rock cover:

Stones 2-6cm (%): 0

Rocks 6-20cm (%): 10

Rocks 20-60cm (%): 10

Big rocks 60-200 cm (%): 30

Rock Outcrop (%): 30

Ground cover:

Bare ground (%): 0

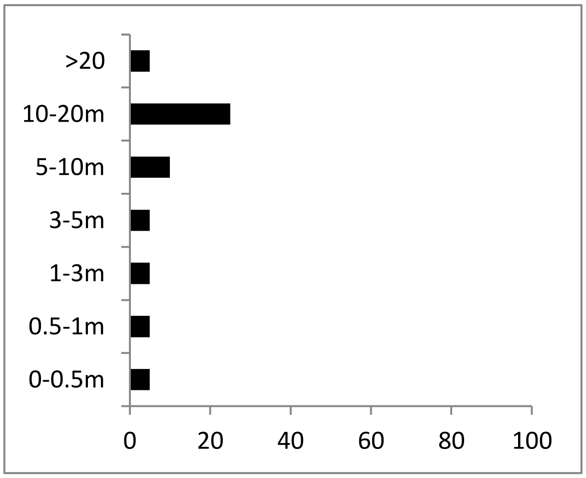
Leaf litter (%): 20

Grass (%): 25

Palm cover (%): 0

Log number: 2

Vegetation Profile, % cover in different height classes:



Fauna Habitat Assessment:

Site Name: Clay 9

Date: **25/5/2015**

UTM Coordinates: 52 203940 Easting, 905 9540 Northing

Elevation (m): 255 m

Habitat value: Low

Vegetation Type: Agricultural land/ricefields

Canopy Cover: 2%

Canopy Height: 7 m

Disturbance:

Fire Impact (0-5): 0

Agriculture(0-5): 5

Cow/horse/Buffalo(0-5): 3

Weeds (0-5): 2

Total: 10 (High)

Rock cover:

Stones 2-6cm (%): 0

Rocks 6-20cm (%): 0

Rocks 20-60cm (%): 0

Big rocks 60-200 cm (%): 0

Rock Outcrop (%): 0

Ground cover:

Bare ground (%): 0

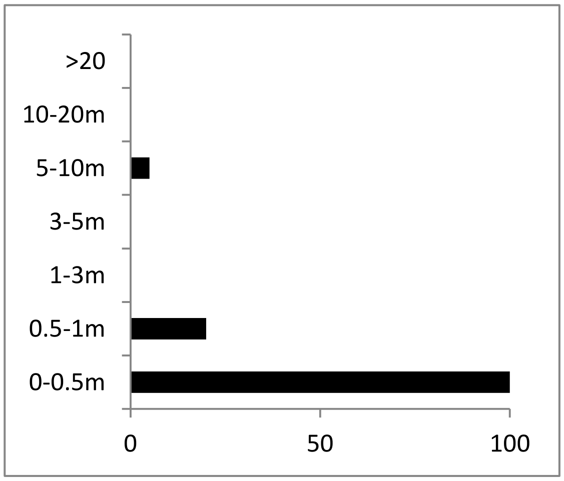
Leaf litter (%): 0

Grass (%): 100

Palm cover (%): 0

Log number: 0

Vegetation Profile, % cover in different height classes:



Appendix 7. Summary of coordinates at 24 fauna point count survey sites.

Site	Easting	Northing	Elevation(m)	Habitat type	Habitat quality
Jetty1	52 207584	906 5439	2	Beach forest	Moderate
Jetty2	52 207670	906 5593	1	Beach forest	Moderate
Plant1	52 207857	906 4224	65	*Eucalyptus alba* woodland	Low
Plant2	52 207861	906 4481	49	*Eucalyptus alba* woodland	Low
Plant3	52 207987	906 4647	50	*Eucalyptus alba* woodland	Low
Mine1	52 209264	906 3205	261	Closed forest	Moderate
Mine2	52 209457	906 3192	270	*Eucalyptus alba* woodland	Moderate
Mine3	52 209151	906 3156	270	Schleichera woodland	Moderate
Mine4	52 208890	906 3040	244	Schleichera woodland	Moderate
Mine5	52 208599	906 2910	247	Schleichera woodland	Low
Mine6	52 208599	906 2910	230	*Eucalyptus alba* woodland	Low
Mine7	52 208422	906 4205	96	*Eucalyptus alba* woodland	Low
Mine8	52 208518	906 4007	114	*Eucalyptus alba* woodland	Moderate
Mine9	52 208222	906 3983	108	*Eucalyptus alba* woodland	Moderate
Mine10	52 207900	906 3892	104	*Eucalyptus alba* woodland	Moderate
Clay1	52 203757	905 8280	295	Closed forest-bamboo	High
Clay2	52 202764	905 8264	306	Closed forest-bamboo	Moderate
Clay3	52 203133	905 9784	146	Bamboo thicket	Low
Clay4	52 202929	905 9647	156	Woodland	Low
Clay5	52 202810	905 9442	189	Woodland	Low
Clay6	52 202777	905 9276	212	Woodland	Low
Clay7	52 202557	905 9310	217	Closed forest	Moderate
Clay8	52 204241	905 9789	208	Bamboo thicket	Moderate
Clay9	52 203940	905 9540	255	Agricultural	Low

Appendix 8. Bat acoustic recorder survey sites and effort.

***Recordings failed at sites 5-7 failed due to technical issues. See also Appendix 9.**

Bat Acoustic Site	Easting	Northing	Elevation (m)	Habitat	Set out date	Pick up date	No. nights
Site 1, Baucau Jetty			2	Beach forest degraded	21-May	26-May	5
Site 2, Baucau Mine I-1	0209373	9063501	280	*Eucalyptus alba* woodland	21-May	26-May	5
Site 3, Baucau Clay (bamboo1)	0203157	9059737	154	Tropical forest (secondary bamboo)	23-May	27-May	4
Site 4, Baucau Clay (bamboo2)	0203194	9059893	169	Tropical forest (secondary bamboo)	23-May	27-May	4
*Site 5, Baucau Mine Site I-1	0203822	9059580	260	*Eucalyptus alba* woodland	25-Jun	27-Jun	2
*Site 6, Baucau Mine Site I-1	0203962	9059347	280	*Eucalyptus alba* woodland	25-Jun	27-Jun	2
*Site 7, Baucau Clay (hut)	0209622	9064324	229	Tropical forest (secondary)	25-Jun	27-Jun	2
Site 8, Baucau Clay (forest)	0209320	9063166	279	Tropical forest (secondary)	25-Jun	27-Jun	2

Appendix 9. Report: Armstrong & Konishi (2015), Bat call identification

Bat call identification

from Baucau, Timor-Leste

Type:	Acoustic analysis
Prepared for:	Colin Trainor
Date:	28 August 2015
Job No.:	SZ349
Prepared by:	Kyle Armstrong and Yuki Konishi Specialised Zoological ABN 92 265 437 422 Tel 0404 423 264 kyle.n.armstrong@gmail.com http://szool.com.au

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1.0 INTRODUCTION

This report by Specialised Zoological includes the results of a survey for bats in the project area near Baucau, Democratic Republic of Timor-Leste based on acoustic recordings and the identification of echolocating bat species from their echolocation calls. It includes information on presence only for those bat species that echolocate, and forms part of a larger environmental assessment by Colin Trainor. There have been relatively few surveys of bats in Timor-Leste, and taxonomic issues remain with a significant proportion of the assemblage. Both the lack of taxonomic resolution and an incomplete understanding of the echolocation call types amongst species impose a challenge for this standard approach to bat surveys based on acoustic recordings.

Identifications and a summary of all bat taxa occurring in Timor-Leste was based on the author's experience developed through several unpublished studies in recent years, which have also informed the country's Biodiversity Decree Law ("Annexure I – Interim List of Protected Species" available from the Timor-Leste Institute for Development Monitoring and Analysis at: http://www.laohamutuk.org/Agri/EnvLaw/div/SpeciesLists.pdf). Generally, both the IUCN Red List (http://www.iucnredlist.org/initiatives/mammals) and the Mammal Species of the World (http://www.departments.bucknell.edu/biology/resources/msw3/) (Simmons 2005) are a primary source of information on the occurrence of bat species worldwide, however both these resources did not have access to a variety of unpublished information when they were compiled. Thus, I have provided an updated checklist for both the island of Timor and Timor-Leste based on the most current information available at present.

2.0 BAT BIODIVERSITY ON THE ISLAND OF TIMOR

Timor is part of the non-volcanic southern archipelago of the Lesser Sunda Islands (also known as Nusa Tenggara), which forms part of the Indo-Australian tectonic plate. It is classified into the Moluccan Division, and the western part of the Wallacea ecoregion—on the Australian side of Wallace's Line but on the Asiatic side of Weber's and Lydekker's Lines. The biota is consequently a mix of Asian and Australasian origin, but with the predominance of the former. According to Corbet and Hill (1992:6), the Moluccan Division is characterised by "very impoverished faunas", with islands east of Lombok typically having low endemism.

There has been relatively little research on the biodiversity of Timor-Leste, but recent studies have highlighted that endemism is actually relatively high despite low overall species richness (Trainor 2010). Few bat surveys have been undertaken on the island of Timor, and the fauna is not yet completely described, nor resolved in terms of their nomenclature and relationships to forms on nearby islands. Thus, levels of endemism have not been established. The earliest and still the most comprehensive published summary of the bats of Timor is the seminal work of Goodwin (1979), who conducted field surveys, an extensive examination of museum collections and a review of the literature to derive a list of taxa. Based on his field surveys and taxonomic examinations, Goodwin listed 22 species of bat from Timor, 11 of which he added, including descriptions of new subspecies.

Further attention was given to the taxonomy of the Timorese bat fauna by Kitchener and colleagues from the Western Australian Museum and the Indonesian Institute of Sciences (LIPI), who collected from West Timor, and included these representatives in taxonomic revisions of several bat groups in Nusa Tenggara (e.g. review in Kitchener and Suyanto 1996; also Kitchener and Suyanto 2002).

The taxonomic summaries of Simmons (2005) list 30 species of bat for Timor. This contrasts sharply with the total of 40 species that are currently listed for the island by the IUCN (**Table 1**). Both lists contain additional species for which there is either only a tenuous basis for inclusion (e.g. *Nycteris javanica*, *Tylonycteris robustula*) or which is complicated by a poor understanding of taxonomy (e.g. *Pipistrellus javanicus* / *P. tenuis, Miniopterus paululus*). Both lists also do not include several other species that have been encountered as part of an environmental impact assessment for a hydropower scheme involving power generation infrastructure in the vicinity of the Ira Lalaro polje and the Paitchau Range. The first survey in March 2004 near the village of Malahara recorded 16 species, of which up to four taxa were new records for the island and possibly species new to science (Pavey and Milne 2004). A second survey in October 2006 north and south of the Paitchau Range recorded 15 species, at least one of which was a new record for the island and also possibly new to science (Armstrong 2007). Another brief informal survey conducted by Helgen (2004). Based on the capture of a species of long-eared bat *Nyctophilus* sp. and the examination of museum skins, most notably of one resembling *Dobsonia moluccensis*, Helgen (2004) compiled from various sources a list of 27 (with a minimum of 25) bat species thought to be on Timor. There have been no surveys since Armstrong (2007) that have added species records (that the author is aware of).

Compiling a revised species list for both the island of Timor and Timor-Leste based on the information in Pavey and Milne (2004), Helgen (2004), Simmons (2005), Armstrong (2007) and the IUCN Red List accounts of 2008 (**Table 1**) is made difficult by the many taxonomic uncertainties. Excluding certain doubtful records or species that may now be extinct on the island (*Dobsonia moluccensis, Nyctimene keasti, Pteropus temminckii, Tylonycteris robustula*), there are 31 species of bat likely to be extant on Timor, of which 28 are known from Timor-Leste. Of the 31 extant species of bat on Timor, one is endemic, there are at least six recognised endemic subspecies (including nominate forms), and there are at least four taxa that might be endemic at either species or subspecies level, pending further taxonomic investigation.

The Interim List of Protected Species under Timor-Leste's Biodiversity Decree Law lists 25 of these species, including those that have only recently been discovered and not yet named or compared taxonomically with similar forms outside the country. Many of the 28 extant bat species listed for Timor-Leste have an IUCN conservation status listing of Least Concern (18 species). However, at least three of those 18 species might be new to science and would therefore need to be re-evaluated at species level. The remaining 10 species are either listed as Vulnerable (two species; with two additional species thought to be extinct on the island also listed as Vulnerable), Near Threatened (1 species), Data Deficient (six species) or Not Evaluated (at least one taxon). Thus, at least a third of the bat species in Timor-Leste are either recognised as being Threatened, or have the potential to be, pending the outcome of future taxonomic and ecological studies.

3.0 METHODS

3.1 Acoustic Recordings

The ultrasonic echolocation calls of bats are produced for spatial orientation and prey detection in flight, but are also useful for species identification because each produces a characteristic signal type. Some signal types are similar, which can make it difficult to distinguish two or three species, but most bats in a particular assemblage are distinct enough to be recognised unambiguously. Analysis of the recordings made using electronic 'bat detectors' take advantage of this. Thus, acoustic surveys for bats can reveal echolocating bat diversity at sampling sites with minimal effort.

Wildlife Acoustics SM2BAT+ bat detectors were chosen because of their ability to make high quality full spectrum recordings in WAV format. External SMX-U1 microphones (with the Knowles FG electret element) were attached with a 3 metre cable. Bat detectors were waterproofed in plastic boxes, and microphones were placed in a funnel made from a plastic drink bottle to reduce the chance of water exposure. The use of funnels slightly reduces the zone of signal detection, but was an unavoidable compromise. The detectors were employed as passive stationary data recorders, being set in position prior to dusk and collected after dawn, and with the microphone capsule tied to trees.

3.2 Analysis of Acoustic Recordings

Data recorded in full spectrum lossless WAC0 format (sampling rate 384 kHz, trigger 6 dB above background; 12 dB gain; set to turn on automatically at sunset and off at sunrise) was converted to high quality bitstream WAV format using Kaleidoscope 3.0.0 software.

A multi-step acoustic analysis procedure developed to process large full spectrum echolocation recording datasets from insectivorous bats (Armstrong and Aplin 2014; Armstrong et al. 2015a) was then applied to the recordings made on the survey. Firstly, the WAV files were scanned for bat echolocation calls using several parameter sets in the software SCAN'R version 1.7.7 (Binary Acoustic Technology), which also provides measurements (in "SonoBat™ compatible output") from each putative bat pulse. The output was then used to determine if putative bat pulses measured in SCAN'R could be identified to species. This was done using a custom [R] language script that performed three tasks: 1. undertook a Discriminant Function Analysis on training data from similar representative call types from Papua New Guinea; 2. from the measurements of each putative bat pulse from

SCAN'R, calculated values for the first two Discriminant Functions that could separate the echolocation call types derived from the analysis of training data, and plotted these resulting coordinates over confidence regions for the defined call types; and 3. facilitated an inspection in a spectrogram of multiple examples of each call type for each recording night by opening the original WAV files containing pulses of interest in Adobe Audition CS6 version 5.0.2. Call types recognised in the recordings were named according to a nomenclatural scheme (**Figure 1**; Armstrong and Aplin 2011; Armstrong et al. 2015a,b), and were noted for each nights recording. A species-level identification was allocated to each call type where possible based on the authors unpublished reference call collection.

3.3 Interpreting echolocation calls—limitations and considerations

1. Taxonomic identification of captures. There is no authoritative field guide for the mammals of Timor-Leste. Identifications were made based on the author's previous field experience (Armstrong 2007), follow up unpublished examinations of museum specimens (Museum and Art Gallery of the Northern Territory, Western Australian Museum) and unpublished DNA barcoding. Capture of specimens and follow up identification work was beyond the scope of this study.

2. Taxonomic identification of echolocation signals. Only some of the call types from the echolocating bats of Timor-Leste can currently be identified to species. The inability to assign all call types to a named species does not automatically imply that species new to science were detected. On the contrary, the majority of the unassigned calls almost certainly belong to described species or other known taxa. As further reference calls become available, it should be possible to retrospectively identify the unallocated calls.

3. The number of call types may not equate to species richness. The tally of documented call types may not simply equate to the same number of bat species, for two reasons: 1) two or more closely related bat species may produce calls that are so similar that they cannot be distinguished reliably using the available methods; and 2) a single bat species may produce more than one call type (e.g. clutter calls, search phase calls, approach phase calls), some of which may resemble the calls of other species.

4. Relative detectability varies amongst species. Detectability varies amongst species based on echolocation call characteristics, particularly the characteristic frequency and amplitude of emitted signals. Some bats produce signals of very low power (for example species of Long-eared Bats *Nyctophilus*) and others produce very high frequency signals that attenuate quickly (for smaller species of *Hipposideros, Harpiocephalus, Kerivoula, Murina*). Calls in either category are possible to detect only when the bat is close to the microphone. The recording equipment chosen in the survey maximised the possibility that these species would be recorded (because of the type of microphone and post recording data processing technique), however they are still likely to be under-represented on recordings.

5. Technical limitations of the recording equipment. Acoustic recording equipment was deployed at eight sites for a total of 32 recording nights. Recordings failed on 18 nights because a corrected gain setting for the new microphone type used was not specified by the manufacturer. The incorrect setting was rectified part-way through the survey and extra sampling sites were included (June 2015) to compensate.

4.0 RESULTS

A total of 14 informative recording sessions was made on the field survey. All represent a full night of passive stationary recording. Site photographs are provided in **Figure 2**. A total of 10 different call types (=species) was distinguished (**Figure 3**), and four of these call types could be allocated to a species through comparison with available unpublished reference calls (**Tables 2** and **3**). The remaining six call types could not be assigned to either species or genus level, though possibilities are given in **Table 4**.

I addition to the acoustic recordings, I examined two photographs of bats sheltered underneath palm leaves (presumably *Corypha utan*) in the project area. These are most likely the Indonesian Short-nosed Fruit Bat *Cynopterus titthaecheilus* (**Figure 4**).

5.0 CONCLUSIONS

1. At least 10 echolocating bat species are present in the project area, with four species able to be identified. The remaining six unidentified call types would need additional follow-up capture work to attribute them to known taxa.

2. One of the detected species is listed in a Threatened category: Canut's horseshoe bat *Rhinolophus canuti timoriensis* (Vulnerable B1ab(iii)), which is also represented as an endemic taxon (at subspecies level) on Timor. Key threats would include disturbance at cave roosts, loss of roosts, and loss of optimal foraging habitat through clearing of forest.

3. No other endemic species were detected, though *Hipposideros diadema* is represented by the nominate form on the island of Timor, and other subspecies elsewhere, and the subspecies *Rhinolophus celebensis parvus* might also be limited to Timor.

4. There was no evidence of the presence of four taxa that are potentially new to science—*Harpiocephalus* aff. *harpia*, *Kerivoula* sp., *Murina* aff. *florium*, *Rhinolophus* aff. *philippinensis*. Only the latter, as well as similar species *Rinolophus montanus,* has been recorded outside the Nino Konis Santana National Park (Armstrong 2006), and hence has a higher probably of being detected around Baucau.

5. At least four species of cave roosting bat were recorded and identified to species (two species of *Rhinolophus; Hipposideros diadema*, *Miniopterus australis*), with several others likely (other *Miniopterus* spp.; *Taphozous* spp.). Thus, up to a maximum of eight out of ten echolocating bat species recorded on the survey use caves for daytime roosting. Aggregations of cave roosting bats are vulnerable to disturbance and increased rates of mortality in these places of refuge.

6. Given that some of the species recorded roost in caves, it is possible that other cave roosting species might also use the project area—especially those that have higher frequency calls with a much shorter detection range than *Miniopterus* and *Rhinolophus*. Glover (1986) refers to "rockshelters" in the vicinity of Baucau, which is on the edge of a limestone plateau. There are observations of bats in caves c. 300 m from project sites near the coast and the large escarpment near the project area is likely to support cave roosting bats. Two known named caves—Lie Siri and Bui Cere—are within 1 km of the project area. Ideally, caves nearby the development would be protected from the possibility of increased human visitation associated with the proposed development.

7. There is very likely to be an undocumented species of Molossidae on Timor based on the call type *25 sFM*. The same call type was noted by Armstrong (2007), who suggested a member of this family based on pulse shape. The harmonic patterns recorded in high quality full spectrum format on the present survey corroborate this suggestion. A candidate species is *Otomops johnstonei*, which is present on nearby Alor Island.

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Table 1. Summary of bat taxa recorded from the island of Timor (IUCN Red List, with links provided for species profiles and their corresponding mapped distributions in the last two columns; Simmons 2005) and the Democratic Republic of Timor-Leste (BDL: Biodiversity Decree Law; revised Timor-Leste list; wt: previous records from West Timor only; ?: record doubtful or taxon probably now extinct; ES: species endemic to Timor-Leste; final tally of accepted extant taxa for Timor-Leste in '[ ]'). 'X' indicates purported presence with nomenclature as per column 2; alternative nomenclature (including subspecies) is given where necessary.

Common name	*Genus species*	IUCN	Simmons 2005	Timor-Leste BDL	Revised Timor-Leste list	IUCN	IUCN profile	IUCN map
PTEROPODIDAE								
Sunda Fruit Bat	*Acerodon mackloti*	*X*	*X*	*X*	*X*	VU A3cd	142	142
Lesser Dog-faced Fruit Bat	*Cynopterus brachyotis*	*X*				LC	6103	6103
Nusatenggara Short-nosed Fruit Bat	*Cynopterus nusatenggara*	*X*				LC	6105	6105
Indonesian Short-nosed Fruit Bat	*Cynopterus titthaecheilus*	*X*	*X*		*X*	LC	6107	6107
Moluccan Naked-backed Fruit Bat	*Dobsonia moluccensis*	*X*			*X (?)*	LC	6779	6779
Western Naked-backed Fruit Bat	*Dobsonia peronii*	*X*	*X*	*X*	*X*	LC	6771	6771
Dawn Bat	*Eonycteris spelaea*	*X*	*X*	*X*	*X*	LC	7787	7787
Dagger-toothed Long-nosed Fruit Bat	*Macroglossus minimus*	*X*	*X*		*X*	LC	12594	12594
Pallas's Tube-nosed Fruit Bat	*Nyctimene cephalotes*	*X*				LC	14963	14963
Keast's Tube-nosed Fruit Bat	*Nyctimene keasti*	*X*	*X*	*X*	*X (?)*	VU B1ab(ii,iii)	136441	136441
Gray Flying-fox	*Pteropus griseus*	*X*	*X*	*P. g. griseus*	*P. g. griseus*	DD	18727	18727
Lombok Flying-fox	*Pteropus lombocensis*	*X*	*X*	*X*	*X*	DD	18733	18733
Temminck's Flying-fox	*Pteropus temminckii*		*X*		*X (?)*	VU A2c	18762	18762
Large Flying-fox	*Pteropus vampyrus*	*X*	*X*	*X*	*X*	NT	18766	18766
Geoffroy's Rousette	*Rousettus amplexicaudatus*	*X*	*X*	*X*	*X*	LC	19754	19754
HIPPOSIDERIDAE								
Bicolored Leaf-nosed Bat	*Hipposideros bicolor*	*X*	*X*	*H. b. hilli*	*H. b. hilli*	LC	10113	10113
Timor Leaf-nosed Bat	*Hipposideros crumeniferus*	*X*	*X*			DD	10124	10124
Diadem Leaf-nosed Bat	*Hipposideros diadema*	*X*	*X*	*H. d. diadema*	*H. d. diadema*	LC	10128	10128

Common name	*Genus species*	IUCN	Simmons 2005	Timor-Leste BDL	Revised Timor-Leste list	IUCN	IUCN profile	IUCN map
Sumban Leaf-nosed Bat	*Hipposideros sumbae*	*X*		*H. s.* aff. *rotiensis*	*H. s.* aff. *rotiensis*	LC	10164	10164
RHINOLOPHIDAE								
Canut's Horseshoe Bat	*Rhinolophus canuti*		*X*	*R. canuti timoriensis*	*R. canuti timoriensis*	VU B1ab(iii)	19528	19528
New Guinea Horseshoe Bat	*Rhinolophus euryotis*	*X*				LC	19540	19540
Kai Horseshoe Bat	*Rhinolophus keyensis*	*X*	*X*	*R. celebensis parvus*	*R. celebensis parvus*	DD	19577	19577
Great Woolly Horseshoe Bat	*Rhinolophus luctus*	*X*				LC	19548	19548
Timorese Horseshoe Bat	*Rhinolophus montanus*	*X*	*X*	*X*	*X* [ES]	DD	136248	136248
Large-eared Horseshoe Bat	*Rhinolophus philippinensis*	*X*		*Rhinolophus* aff. *philippinensis*	*Rhinolophus* aff. *philippinensis*	LC	19560	19560
NYCTERIDAE								
Javan Slit-faced Bat	*Nycteris javanica*	*X*				VU A3c	14932	14932
MINIOPTERIDAE								
Little Bent-winged Bat	*Miniopterus australis*	*X*	*X*	*X*	*X*	LC	13562	13562
Large Bent-winged Bat	*Miniopterus magnater*	*X*	*X*	*X*	*X (wt)*	LC	13566	13566
Australasian Bent-winged Bat	*Miniopterus oceanensis*	*X*	*Miniopterus schreibersii*	*X*	*X*	LC	136337	136337
Philippine Bent-winged Bat	*Miniopterus paululus*	*X*				DD	136233	136233
Small Bent-winged Bat	*Miniopterus pusillus*	*X*	*X*	*X*	*X*	LC	13569	13569
Shortridge's Bent-winged Bat	*Miniopterus shortridgei*	*X*	*X*			DD	136827	136827
VESPERTILIONIDAE								
Unnamed Hairy-winged Bat	*Harpiocephalus* aff. *harpia*			*Harpiocephalus* aff. *harpia*	*Harpiocephalus* aff. *harpia*	LC	9736	9736
Unnamed Woolly Bat	*Kerivoula* sp.			*Kerivoula* sp.	*Kerivoula* sp.	—	—	—
Unnamed Flute-nosed Bat	*Murina* aff. *florium*			*Murina* aff. *florium*	*Murina* aff. *florium*	LC	13939	13939
Large-footed Myotis	*Myotis adversus adversus*				*X (wt)*	LC	14138	14138
Greater Long-eared Bat	*Nyctophilus timoriensis*	*X*	*X*	*Nyctophilus* sp.	*X*	DD	15010	15010
Javan Pipistrelle	*Pipistrellus javanicus*	*X*	*X*		*X*	LC	17344	17344
Least Pipistrelle	*Pipistrellus tenuis*	*X*				LC	17368	17368
Sody's Yellow House Bat	*Scotophilus collinus*	*X*	*X*		*X*	LC	136612	136612

Common name	*Genus species*	IUCN	Simmons 2005	Timor-Leste BDL	Revised Timor-Leste list	IUCN	IUCN profile	IUCN map
Lesser Asiatic Yellow House Bat	*Scotophilus kuhlii*	*X*				LC	20068	20068
Northern Broad-nosed Bat	*Scotorepens sanborni*	*X*	*X*		*X (wt)*	LC	14947	14947
Greater Flat-headed Bat	*Tylonycteris robustula*	*X*	*X*		*X (?)*	LC	22578	22578
EMBALLONURIDAE								
Bare-rumped Sheath-tailed Bat	*Saccolaimus saccolaimus*	*X*	*X*		*X*	LC	19802	19802
Indonesian Tomb Bat	*Taphozous achates*	*X*	*X*	*X*	*X*	DD	21453	21453
Black-bearded Tomb Bat	*Taphozous melanopogon*	*X*	*X*	*X*	*X*	LC	21461	21461
Totals		**40**	**30**	**25**	**35 [28]**			

Table 2. Species identified in the present survey from all recording units, nights and sites.

Date	Site	***20 cFM***	***25 sFM Molossidae***	***25 cFM***	***35 cFM***	***45 st.cFM***	***54 st.cFM***	***63 st.cFM M. australis***	***55 mCF H. diadema***	***72 lCF R. canuti***	***86 lCF R. celebensis***
SM2BAT 4185											
24/05/2015	Site 3, Baucau Clay, bamboo1	—	—	X	X	—	X	X	—	X	X
25/05/2015	Site 3, Baucau Clay, bamboo1	X	—	—	—	X	X	X	—	X	X
26/05/2015	Site 3, Baucau Clay, bamboo1	X	—	—	X	—	X	X	—	—	—
27/06/2015	Site 8, Baucau Clay, forest	X	—	—	X	X	X	X	X	X	X
SM2BAT 7849											
24/05/2015	Site 4, Baucau Clay, bamboo2	—	—	—	—	—	—	X	—	X	X
25/05/2015	Site 4, Baucau Clay, bamboo2	—	—	—	—	—	—	X	—	X	X
26/05/2015	Site 4, Baucau Clay, bamboo2	X	—	—	—	—	—	X	—	X	—
SM2BAT 8066											
21/05/2015	Site 1, Baucau Jetty	—	X	—	—	X	X	X	X	X	X
22/05/2015	Site 1, Baucau Jetty	—	—	—	—	X	—	X	X	—	X
23/05/2015	Site 1, Baucau Jetty	—	—	—	X	—	X	X	X	X	X
24/05/2015	Site 1, Baucau Jetty	X	—	—	—	X	X	X	X	X	X
SM2BAT 10890											
21/05/2015	Site 2, Baucau, Eucalypt woodland	—	—	X	—	X	X	X	—	—	—
22/05/2015	Site 2, Baucau, Eucalypt woodland	—	—	—	—	—	—	X	—	X	—
23/05/2015	Site 2, Baucau, Eucalypt woodland	—	—	—	—	X	—	—	—	—	—

Note: All recordings failed at: Site 5 ('Baucau Mine'; 2 nights), Site 6 ('Baucau Mine'; 2 nights), site 7 ('Baucau Clay'; 2 nights).

Table 3. Summary of species identified, richness and sampling effort (numbers in brackets are actual number of nights deployed at each site).

Call type	Species	Site 1	Site 2	Site 3	Site 4	Site 8
20 cFM		X	—	X	X	X
25 sFM	Molossidae	X	—	—	—	—
25 cFM		—	X	X	—	—
35 cFM		X	—	X	—	X
45 st.cFM		X	X	X	—	X
54 st.cFM		X	X	X	—	X
63 st.cFM	*M. australis*	X	X	X	X	X
55 mCF	*H. diadema*	X	—	—	—	X
72 ICF	*R. canuti*	X	X	X	X	X
86 ICF	*R. celebensis*	X	—	X	X	X
Total Richness per site		**9**	**5**	**8**	**4**	**8**
Total recording nights		**4 (6)**	**3 (6)**	**3 (6)**	**3 (6)**	**1 (2)**

Table 4. Comments on the taxonomic identification of the bat call types defined in this survey.

20 cFM
Attributable to one of the sheath-tailed bats on Timor—the Indonesian Tomb Bat *Taphozous achates*, Black-bearded Tomb Bat *T. melanopogon*, or the Bare-rumped Sheath-tailed Bat *Saccolaimus saccolaimus*, which produces a variety of call types. Capture of bats would be required for confirmation.
25 sFM **Molossidae**
Call shape more typical of a bat in the Molossidae, such as *Chaerephon* or *Otomops*. Harmonic patterns were also diagnostic of this family. None of these has ever been captured on Timor, but similar calls were recorded by Armstrong (2007) (without harmonic information), with *Chaerephon jobensis* and *Otomops johnstonei* (present on Alor Island; Kitchener 1992) suggested as possibilities. The latter is more likely given the characteristic frequency. These recordings confirm the presence of a representative of the family on Timor.
25 cFM
Most likely attributable to the black-bearded tomb bat *Taphozous melanopogon* based on reference calls described in Pottie et al. (2005), however reference calls are not available from Timor, and have not been compared with those from *T. achates*.
35 st.cFM
Possibly attributable to a large vespertilionid such as Sody's Yellow House Bat *Scotophilus collinus* (cf. the calls of *S. kuhlii* in Pottie et al. 2005). Capture is required for identification. There was some variation in pulse structure and characteristic frequency.
45 st.cFM
One of several candidate species in the Miniopteridae or Vespertilionidae. Capture, and DNA barcoding would be required for identification. The variation ascribed to this call type might encompass more than one species.
54 st.cFM
One of several candidate species in the Miniopteridae or Vespertilionidae. Capture, and DNA barcoding would be required for identification.
63 st.cFM Miniopterus australis
Identification made based on reference calls collected by Armstrong (2007).
55 sCF Hipposideros diadema diadema
Identification made based on reference calls collected by Armstrong (2007).
72 lCF Rhinolophus canuti timoriensis
Identification made based on reference calls collected by Armstrong (2007).
86 lCF Rhinolophus celebensis parvus
Identification made based on reference calls collected by Armstrong (2007), and information in Pavey and Milne (2004).

Code	Description	Example
CF	**Constant Frequency main Body Sub Type (BST)**	*sCF* *mCF*
sCF	Short duration (<15 ms)	
mCF	Medium duration (15 – 30 ms)	*lCF*
lCF	Long duration (>30 ms)	
FM	**Frequency Modulated main Body Sub Type (BST)**	*bFM* *sFM*
bFM	Broadband, slightest degree of curvature only, no significant development of serpentine component (*sFM*)	*cFM*
cFM	Curved, simple or curvilinear trace	*cvFM*
cvFM	Convex curved, essentially cFM rotated 180°	*fFM*
fFM	Flat or with a very slight curve, narrowband, not *CF*	*sFM*
sFM	Serpentine, generally S-shaped	
	Initial Frequency Sweep (IFS)	*i.* *sh.* *st.*
i.	Inclined, a narrowband increasing frequency sweep	
sh.	Short, shallow or narrowband frequency sweep	
st.	Steeply decreasing, broadband frequency sweep	
	Terminating Frequency Sweep (TFS)	*.d* *.h*
.d	Drooped, decreasing frequency sweep following the characteristic frequency in the main body of the call	
.h	Hooked, increasing in frequency	

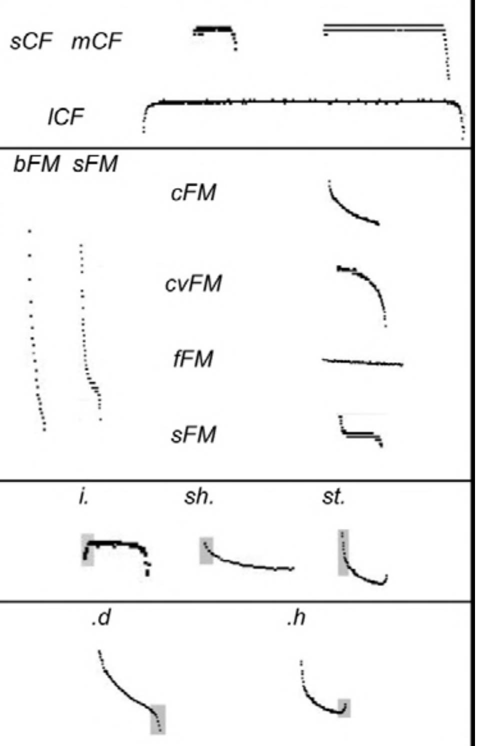


Figure 1. Echolocation call categories based on the morphology of the dominant type of search-phase pulses in high quality sequences (adapted from de Oliveira 1998a,b; Corben and O'Farrell 1999; Gannon et al. 2004; Armstrong and Aplin 2011; Armstrong et al. 2015a,b; examples are from a Zero Crossings Analysis output and are not scaled equally). Pulses generally consist of three main sections: an initial frequency sweep (IFS), followed by the main body (BST: Body Sub Type), and ending in a terminating frequency sweep (TFS). The shape of the pulse is represented by the codes in the form 'IFS.BST.TFS', prefixed by a value representing the mean characteristic frequency in kHz.

Figure 2. Photographs of acoustic recording sites (photos: C. Trainor).

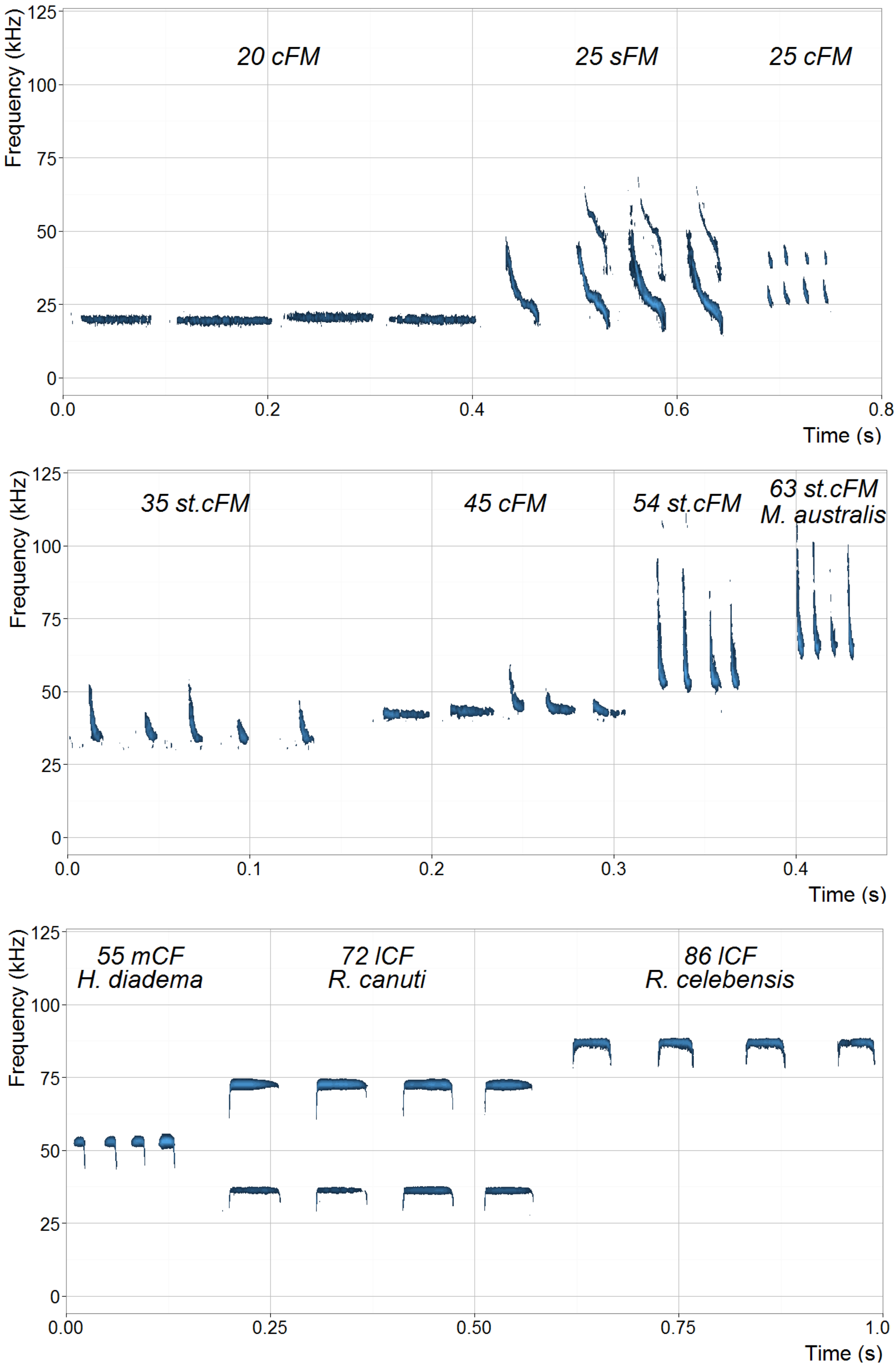


Figure 3. Representative echolocation pulses call sequence portions of the species identified (time between pulses is compressed).

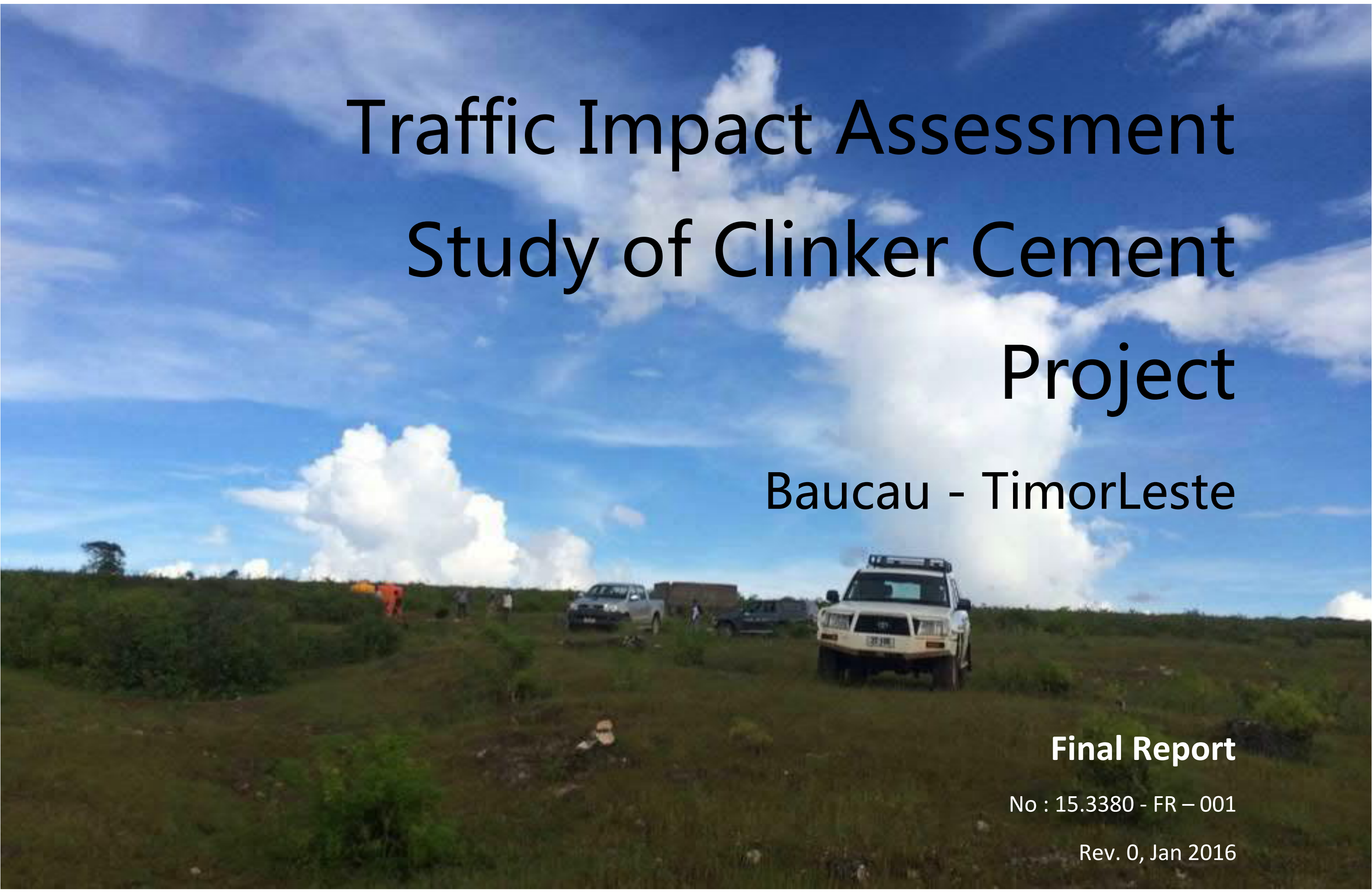
Figure 4. Photographs of the Indonesian Short-nosed Fruit Bat *Cynopterus titthaecheilus* sheltered underneath palm leaves (presumably *Corypha utan*) in the project area (photos: C. Trainor).

Appendix 6 Traffic Impact Asessment Study

Cement

Your Dream, We will Build!

TL CEMENT Lda.



Traffic Impact Assessment Study of Clinker Cement Project

Baucau - TimorLeste

Final Report

No : 15.3380 - FR – 001

Rev. 0, Jan 2016

Prepared by:

PT. **BITA** BINA SEMESTA

CONTENTS

GLOSSARY

Annual Average Daily Traffic	The total volume of traffic passing a point or segment of a highway facility in both directions for one year divided by the number of days in the year.
Capacity	The maximum sustainable flow rate at which vehicles or persons reasonably can be expected to traverse a point or uniform segment of a lane or roadway during a specified time period under given roadway, geometric, traffic, environmental, and control conditions; usually expressed as vehicles per hour, passenger cars per hour, or persons per hour.
Centroid Connectors	Links that connect centroid nodes with the model network. These can represent local streets not included in the model network. Centroid Connectors provide the linkage between the trips associated with the TAZ land uses and the roadway segments (or links).
Centroids	They represent the center of activity for a transportation analysis zone (TAZ). This is not the geometric center of the zone.
Demand	The number of users desiring service on the highway system usually expressed as vehicles per hour or passenger cars per hour.
Demand to capacity ratio	The ratio of demand flow rate to capacity for a traffic facility.
External Station	A location where a roadway crosses the outside boundary of a travel demand model or zone cumulative analysis.
Flow rate	The equivalent hourly rate at which vehicles, bicycles, or persons pass a point on a lane, roadway, or other traffic way; computed as the number of vehicles, bicycles, or persons passing the point, divided by the time interval (usually less than 1 h) in which they pass; expressed as vehicles, bicycles, or persons per hour.
Geometric condition	The spatial characteristics of a facility, including approach grade, the number and width of lanes, lane use, and parking lanes.
Lateral clearance	(1) The total left- and right-side clearance from the outside edge of travel lanes to fixed obstructions on a multilane highway; (2) the right-side clearance distance from the rightmost travel lane to fixed obstructions on a freeway.
Level of service	A qualitative measure describing operational conditions within a traffic stream, based on service measures such as speed and travel time, freedom to maneuver, traffic interruptions, comfort, and convenience
Link	A segment of highway ending at a major intersection on an urban street or at a ramp merge or diverge point on a freeway. Links have a node at each end
Internal trip	a trip with both its origin and its destination located inside of the study area. If either trip ends is outside the study area, it is an external trip. If both trip ends are outside the study area, it is a through trip
External trip	a trip with either its origin or its destination located outside of the study area. The external trip end is assigned to an external station
Through trip	a trip has both trip ends outside the study area
Off-peak flow traffic	A time period during any given day when the traffic volume is normally the least
Peak-flow traffic	A time period during any given day when the traffic volume is normally

	the heaviest. Peak-flow traffic may last up to two hours in some locations and is normally for the a.m. commute to work and the p.m. commute home from work
Peak-hour factor	The hourly volume during the maximum-volume hour of the day divided by the peak 15-min flow rate within the peak hour; a measure of traffic demand fluctuation within the peak hour
Pcuph	Passenger car unit per hour
Nodes	(1) link endpoints, typically intersections or points representing changes in link attributes (2) Indicates the intersections of links
Network	A graphical and/or mathematical representation of a region's transportation infrastructure and services, comprising links and nodes and their corresponding characteristics. Also refers to the actual networks of highways, transit, and other modes
Shoulder	A portion of the roadway contiguous with the traveled way for accommodation of stopped vehicles, emergency use, and lateral support of the subbase, base, and surface courses
Spacing	The distance, in meters, b etween two successive vehicles in a traffic lane, measured from the same common feature of the vehicles (e.g., rear axle, front axle, or front bumper)
Speed	A rate of motion expressed as distance per unit of time
Space mean speed	(1) The harmonic mean of speeds over a length of roadway; (2) an average speed based on the average travel time of vehicles to traverse a segment of roadway; in kilometers per hour
Spot speed	The instantaneous speed of a vehicle at a specified location
Time mean speed	The arithmetic average of individual vehicle speeds passing a point on a roadway or lane, in kilometers per hour
Traffic control device (TCD)	Signs, signals, markings, and devices placed on, over, or adjacent to a street or highway by an authority of a public body having jurisdiction to regulate, warn, or guide traffic.
Traffic volume	Amount of traffic that travels any given roadway during any given time period.
T-Intersection	An intersection where two roads meet (whether or not at right angles) and one of the roads ends
Undersaturation	A traffic condition in which the arrival flow rate is lower than the capacity or the service flow rate at a point or uniform segment of a lane or roadway
Unsignalized intersection	An intersection not controlled by traffic signals
Volume	The number of persons or vehicles passing a point on a lane, roadway, or other traffic-way during some time interval, often 1 h, expressed in vehicles, bicycles, or persons per hour
Volume-to-Capacity Ratio (v/c)	The ratio of the traffic flow rate to the capacity of the road
Zone	The basic geographical unit of analysis for conventional travel forecasting. All locations in a study area are contained in one and only one analysis zone, the number and size of which depend on the scale and scope of the modelling effort. Zones should be as homogenous as possible with respect to the associated travel behaviour

EXECUTIVE SUMMARY

TL Cement LDA, a privately-owned company, proposes to construct a Greenfield cement manufacturing project in Baucau Municipality, Timor-Leste. The project will produce approximately 1.65 million tons per annum (Mtpa) of Portland cement clinker. The traffic impact assessment study has been conducted to predict the impact to the traffic during the construction and operation phase of this cement manufacturing project, as well as setting up the mitigation measures for negative impacts.

Traffic counting has been conducted in six locations for six hours of each location. The location was chosen to describe baseline traffic condition around project area and around city as well. The location in the city was chosen to give description of traffic condition as well as comparing with its hinterland. The traffic counting was conducted in six hour. Six hour counting is divided into 3 periods of 2 hours (morning peak, mid-day peak, and afternoon peak).

The road network is classified into two functional classes, i.e. arterial and collector roads. Road width varies from 4 to 5 meters, resulting a road capacity of 900 pcuph and 1,227 pcuph respectively. Based on the traffic calculation, the volume capacity ratio is between 0.2 - 0.7. It can be concluded that road capacity is still sufficient to accomodate current traffic demand.

During construction phase, there will be impact on traffic flows from various activities, as follows:

- There will be 1,000 persons per day from Baucau work in both clay deposit and Clinker Plant. There will be an additional traffic flow to and from clay deposit and Clinker Plant of 18 pcuph and 102 pcuph respectively.
- Daily mobillisation of heavy vehicle transporting construction materials to clay deposit (4 trucks) and Clinker Plant (7 trucks). Accordingly, there will be additional traffic flow due to transportation of construction materials, i.e. 26 pcuph.

Based on the prevailing standard, road networks performance during construction phase is still in good condition.

During operation phase, there will be impact on traffic flows from various activities, as follows:

- Clay (0.41 mio tonnes/year) will be transported from quarry to Plant using a dump truck with a capacity of 25 tonnes. Accordingly, it could generate approx. 4 truck trips per hour (330 days, 12-hours per day), so there will be additional traffic flow of 10 pcuph.
- Finished product (cement) will be delivered from Plant (Baucau) to local market, i.e. Dili. Up to 0.5 million tonnes per annum of finished product will be transported using trucks to Dili. If using 25-ton trucks to transport, it could generate approx. 5 truck trips per hour (330 days, 12-hours per day), so there will be additional traffic flow of 12 pcuph.
- There will be 700 persons per day work during operation phase. It is assumed that all the worker stay in Baucau city, so they will commute from the city to clinker plant and from the city to clay deposit. There will be additional traffic from the city to clay deposit of 13 pcuph and from the city to Clinker Plant of 71 pcuph respectively.

Based on the prevailing standard, road networks performance during operation phase is still in good condition. Hence, the Government of the Democratic Republic of Timor-Leste plans to undertake the National Road No. 1 Upgrading Project to upgrade the 118 km road from capital city Dili to Baucau. The project involves the widening of the current 3.2 - 4.5 m road to 6.0 m width asphaltic concrete

pavement. By implementing the above project, it is believed that the road network will be in better performance as more vehicles could be accommodated.

To manage the impact of traffic both in the construction and the operation phases, managing traffic is essential to providing a safe construction and operation activities. Traffic can include cars, utilities, delivery trucks, excavators, etc. The safe construction and operation activities can be achieved by careful planning and by controlling vehicle operations.

The traffic management plan should be regularly monitored and reviewed to ensure whether it is effective and to take into account any changes during construction and operation activities. All workers should be familiar with the traffic management plan and receive sufficient information, instruction, training, and supervision.

1 INTRODUCTION

1.1 Brief Project Description

TL Cement LDA, a privately-owned company, proposes to construct a Greenfield cement manufacturing project in Baucau Municipality, Timor-Leste. The project will produce approximately 1.65 million tons per annum (Mtpa) of Portland cement clinker.

Clinker refers to small lumps (3.0-25.0 mm diameter), produced by heating limestone and other materials such as clay and sand in a cement kiln. Clinker, if stored in dry conditions, can be kept for several months without appreciable loss of quality. Because of this, it can easily be handled by ordinary mineral handling equipment; clinker is traded internationally in large quantities. Clinker is then ground to a fine powder, along with gypsum and other substances to produce useable cement.

The proposed project will provide cement for both domestic use and international sale. A feasibility study is currently being undertaken to demonstrate the commercial viability of the project.

The proposed project represents a significant investment of approximately $350 million and the largest industrial project undertaken in Timor-Leste to date. It is anticipated to create 1000 jobs at the peak of the construction. It will then continue to have 700 permanent employees during operation. The project aims to develop local capacity and will develop a training center.

The spin off benefit would be indirect employment to local community members, through the multiplier effect due to downstream socio-economic benefits and consequent improvement in the living conditions of local population in the project area.

A. <u>Cement Clinker Plant</u>

The plant includes clinkerisation and cement grinding facilities with a rated capacity of 5,000 tons per day (tpd) of clinker and 100 tons per hour (tph) of cement. The plant also includes a waste heat recovery (WHR) power plant.

Up to 60% of 0.53 Mtpa of cement will be sold in the local markets and balance 40% will be shipped to Australia in 8,000 Deadweight-Ton (DWT) ships either in bulk or in. Balance clinker of 1.15 Mtpa will be shipped in vessels of 40,000 DWT ships to Australia.

The project involves developing a green field plant including, but not limited, to the engineering, design, manufacturing and supply of new equipment for cement plant, a waste heat recovery based power plant, a captive thermal power plant of approx. 30 MW and Port (Double wharf jetties) about 1.5-2 Km from the plant site.

B. <u>Thermal Power Plant bottom and fly ash utilization</u>

The waste from the thermal power plant will be fly ash and bottom ash. The total ash will be utilised in the cement grinding for producing PPC based on the coal data and ash in the coal the fly/bottom ash generation will be approximately 50 t/day i.e approx. 16500 t/annum. This will produce around 66000 t/a of PPC based on 25% ash in PPC. All ash from the thermal power plant will be transported pneumatically to the cement grinding section.

C. <u>Mines and Raw Materials</u>

The raw and fuel material requirements for the proposed plant are to be met from different sources as given in Table below.

Table 1 Raw Materials

No.	Material	Source	Source Locality	Remarks
1.	Limestone	Local	Suco Tirilolo, Bahu, Caibada, Triloca, Bucoli, Baucau Municipality	Primary raw material. Transported from mine site to crusher by trucks.
2.	Clay	Local	Suco Wailacama, Baucau administrative post in Baucau municipality	A corrective material. Transported from quarry to plant by road.
3.	Iron Ore	Import	Australia	A corrective material. Transported to Timor-Leste by ship or barge, offloaded at jetty, and transported to plant by belt and Pipe conveyor.
4.	Gypsum	Import	Australia or other	A corrective material. Transported to Timor-Leste by ship or barge, offloaded at jetty, and transported to plant by belt and pipe conveyor.
5.	Coal	Import	Australia/ Indonesia	Fuel source and corrective material. Transported to Timor-Leste by ship or barge, offloaded at jetty, and transported to plant by belt and Pipe conveyor.

D. Limestone Deposit

The limestone deposit is accessible from Baucau by a tar road. The mine is located about 1 km from the main road and Bucoli village. The mining area is located around 0.5 km from the coastline where a jetty is proposed to be constructed. The limestone concession area (I-1) which shall meet the initial limestone requirement of the plant covers an area of 576 ha. The deposit area is generally undulating and hilly. As observation result, the limestone bearing area is covered by thick or scattered trees, thorny bushes and tall grass.

E. Clay Deposit

Clay is found to occur close to the plant site in Suco Wailacama in Baucau administrative post, less than 10 km west of the plant site. Clay shall be used as corrective to compensate for silica and alumina deficiency in the raw mix. Clay is proposed to be transported to the plant site by trucks.

F. Jetty

A dedicated jetty is proposed at a distance of 2 km from the plant site. Inbound material, (e.g., coal, gypsum, iron ore) and outbound clinker shall be transported between the plant and the jetty by a 0.5 km long conveyor belt + 1.5 km Pipe Conveyor (fully enclosed). The maximum load during unloading is estimated as 1000 tons per hour and during loading is estimated as 1000 tons per hour.

G. Utilities

a. Power

Power will be supplied by captive thermal power plant of approximately 30 mega-watts (MW) capacity and Waste Heat Recovery power plant.

Power for initial phase of plant operation when cement grinding is commissioned will be from grid power. Tapping from the nearby grid line of 20 KV will be tapped and step down to 11 KV at the plant substation. Generator sets will be utilized for construction power.

Emergency power requirement for initial commissioning of cement grinding is not required. For full plant 1.5 MW genset will be required. Thermal power plant shall include black start power requirement separately.

b. Water Supply

The water requirement for the cement project shall be met from groundwater by drilling bore wells. A makeup water supply of approximately 3,150 m^3/day is required for operations including requirement of mines, colony and green belt which may be possible to obtain this from one or two boreholes.

An underground aquifer is reported to occur below the mining blocks. As there is no industry in the area, the exploitation of water resources during the operation is not expected to adversely affect the water availability in the area for other competing users.

A detailed hydrogeological study is proposed to be carried out to assess the availability of groundwater in the area. Water shall be required for:

- Process Water Circuit;
- Cooling water (required for machine cooling);
- Make-up water shall be provided while re-circulating water shall be in a close loop;
- Water required for township;
- Water for on-site facilities;
- Construction and operations (dust suppression).

c. Waste Water

The cement plant is being designed as a Zero Discharge facility and there shall be no discharge of waste water outside the plant premises. All the process waste water shall be treated in Water Treatment Plant and reused for plantation purposes. The waste water generated from domestic activities shall also be treated and reused for dust suppression, green belt development to the extent possible.

d. Solid Waste

Domestic solid waste generated from plant and jetty area shall be segregated and will be sent to waste disposal site as allocated by the local administrative authorities.

1.2 Location of Study

The proposed cement plant and marine jetty are located in Suco Tirilolo, Aldeia Osso-ua, in the Baucau administrative post of Baucau municipality, Timor-Leste. The location is about 120 km east of Dili and approximately 16 km west of Baucau.

The Proponent has been granted a Prospecting License for limestone over three blocks, including, Block I-1 (Bucoli North Area-1), covering areas of 576 Ha. The prospecting blocks are spread over Sucos Tirilolo, Bahu, Caibada, Triloca, Bucoli, and Wailili in administrative posts of Baucau, Vemasse and Venilele in Baucau municipality.

Sources of clay are located at Suco Wailacama within 10 km from proposed plant site. Corrective iron ore and additive gypsum are proposed to be procured from Australia. Coal will be used as a fuel for the kiln and power supply at the cement plant and is proposed to be procured from either Indonesia or Australia. The location of plant, mines (Block I-1) and jetty are shown in figure below.

Source : *https://commons.wikimedia.org/wiki/File:Sucos_Baucau.png*
https://www.mof.gov.tl/about-the-ministry/statistics-indicators/sensus-fo-fila-fali/download-suco-reports/baucau-suco-reports/

Figure 1 Location of TL Cement Development Project

1.3 Scope of Works

According to scope of works from WorleyParsons, the traffic impact assessment study will assess the following task:

- Identifying the transportation planning and transportation network (road and public transportation) existing of Baucau around the studied area.
- Predict and calculate the generation and attraction of the developed area.
- Conduct survey traffic count in road and intersections in surrounding area.
- Conduct corridor and travel time survey to identify the existing road and intersections condition.
- Analyse the traffic circulation of external traffic at the road network and intersections in surrounding area.
- Managing the interface at the road network and intersections in surrounding area.
- Analyse option of entry/exit gate configuration, report on options and propose modification as needed.
- Planning of proposed street furniture for alternatives.
- Recommend and investigate appropriate mitigation measures associated with the development.

2 METHODOLOGY

2.1 Data Collection

Transport study consisted of spot speed at link, geometric of link and intersection, and traffic volume studies, both at link (between two intersections) and at the intersection. Traffic volume study was conducted to determine the number, movements, and classifications of roadway vehicles at a given location. These data can help to identify critical flow time periods, and determine the existing conditions. Traffic counting was conducted during the peak flow period with 15-minute intervals and using manual method.

Manual counts were typically used to gather data for determination of vehicle classification, turning movements, and direction of travel. These manual counts were recorded using tally sheets. The data was recorded with a tick mark on a pre-prepared field form. A watch or stopwatch was necessary to measure the desired count interval.

Intersection counts were used for timing traffic signals, designing channelization, planning turn prohibitions, computing capacity, analyzing high crash intersections, and evaluating congestion. A single observer was placed at each approach for very light traffic conditions otherwise two observers were placed.

Speed is an important transportation consideration because it relates to safety, time, comfort, convenience, and economics. In these transport studies, spot speed data was collected. Spot speed studies are used to determine the speed distribution of a traffic stream at a specific location. The data gathered in spot speed studies are used to determine vehicle speed percentiles, which are useful in making many speed-related decisions.

Spot speed data was gathered using stopwatch method over a relatively short period of time to get a sample size of at least 30. The spot speed study length was determined for 50 meters as average speed of the traffic stream below 30 km/h. These speed data were used to determine vehicle speed percentiles, which were useful in making many speed-related decisions and the existing road performance**. Figure 2** illustrates a typical layout for conducting a spot speed study using a stopwatch.

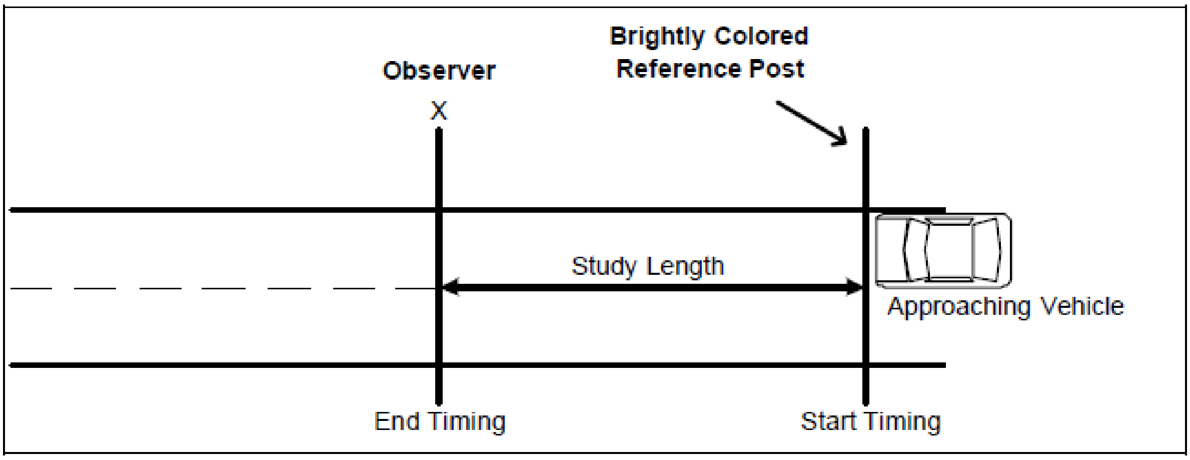


Figure 2 Stopwatch Spot Speed Study Layout

2.2 Intersection Control

An intersection is the area where two or more streets join or cross at-grade. The intersection includes the areas needed for all modes of travel: pedestrian, bicycle, motor vehicle, and truck. Thus, the intersection includes not only the pavement area, but typically the adjacent sidewalks and pedestrian curb cut ramps. Intersections are a key feature of street design in four res pects:

- **Focus of activity -** The land near intersections often contains a concentration of travel destinations.
- **Conflicting movements -** Pedestrian crossings and motor vehicle and bicycle turning and crossing movements are typically concentrated at intersections.
- **Traffic control -** At intersections, movement of users is assigned by traffic control devices such as yield signs, stop signs, and traffic signals. Traffic control often results in delay to users traveling along the intersecting roadways, but helps to organize traffic and decrease the potential for conflict.
- **Capacity -** In many cases, traffic control at intersections limits the capacity of the intersecting roadways, defined as the number of users that can be accommodated within a given time period.

2.3 Traffic Counting

Traffic counting has been conducted in six locations for six hours of each location, these locations can be seen on **Figure 3**. The location was chosen to describe baseline traffic condition around project area and around city as well. The location in the city was chosen to give description of traffic condition as well as comparing with its hinterland.

The traffic counting were conducted in six hour. Six hour counting is divided into 3 period of 2 hours (morning peak, mid-day peak, and afternoon peak).

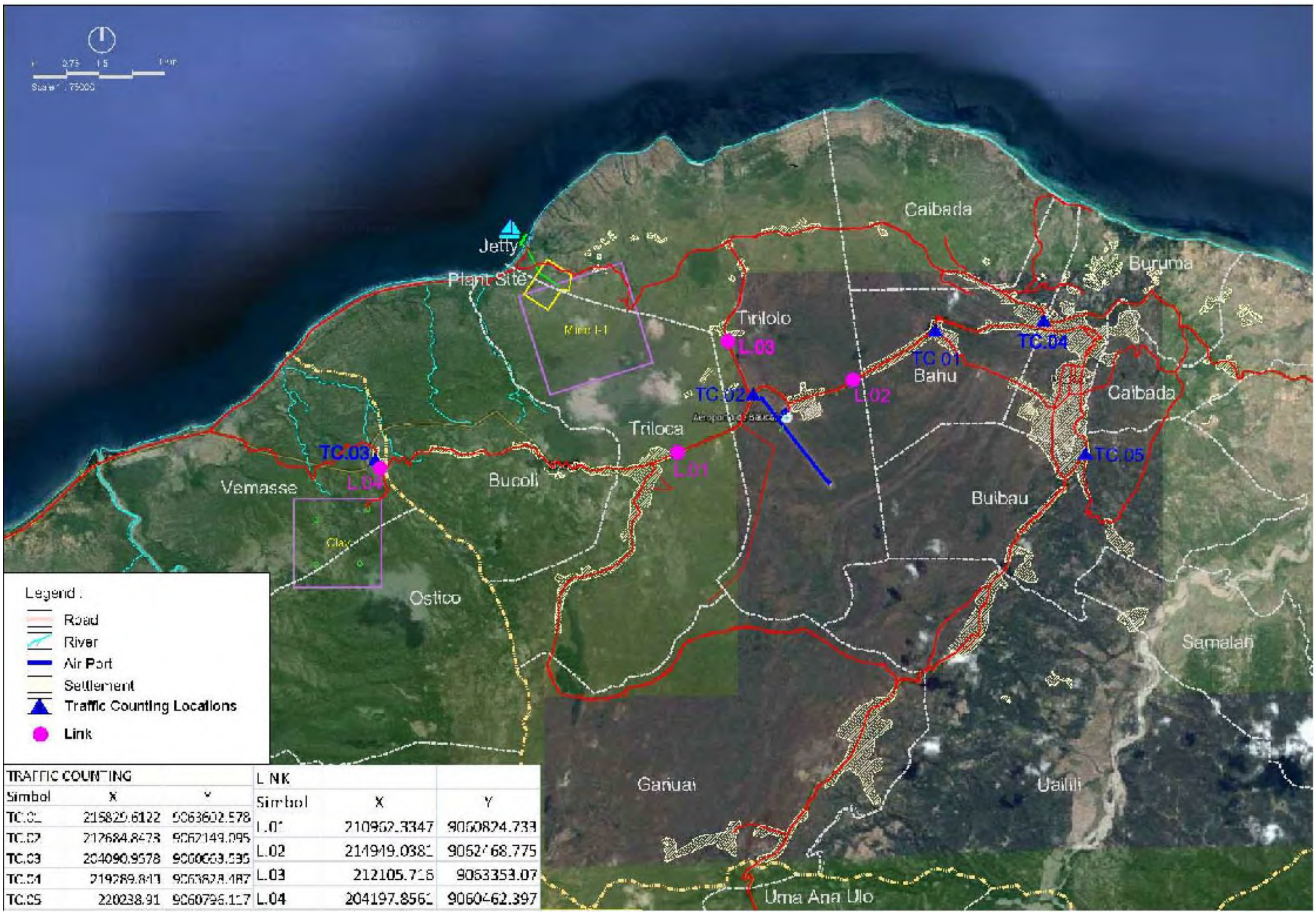


Figure 3 Traffic Counting Location Survey

2.4 Data Analysis

2.4.1 Modeling Approach

Figure 4 shows the main structure of modeling approach used in this research. Traffic related indicators such as link flows, speeds and times, hence in network-wide level could be reproduced from the traffic assignment model.

First of all, inputs data related to trip matrix as the demand side and road network database as the supply side of transport system in the base year case have to be provided, as well as the trip matrices and network databases for alternative scenarios that were tested. Estimation method to obtain trip matrices was adapted, such as maximum entropy matrix estimation (ME2). Assignment process was conducted using SATURN (Van Vlient, 1994) with input data that had been adapted to the characteristic of road network and traffic in Timor-Leste.

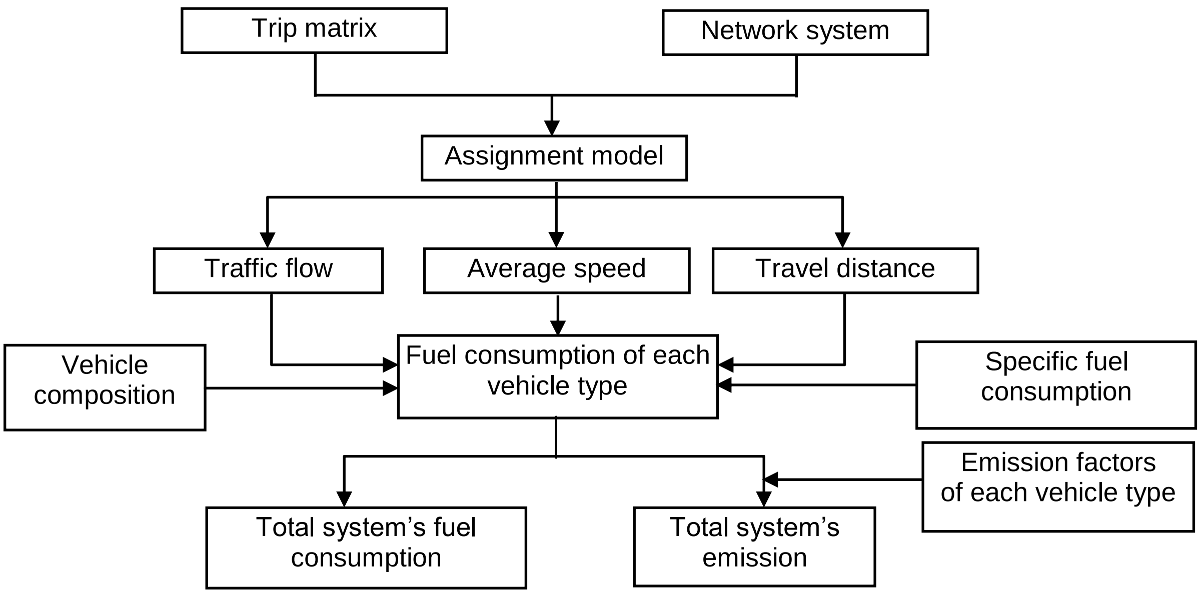


Figure 4 Main Structure of Modeling Approach

2.4.2 Zoning Design

Traffic was modeled to represent study area (Baucau subdistrict) using zoning system (based on suco) and road network, with link represent road segment and node represent intersection, as shown in **Figure 5**.

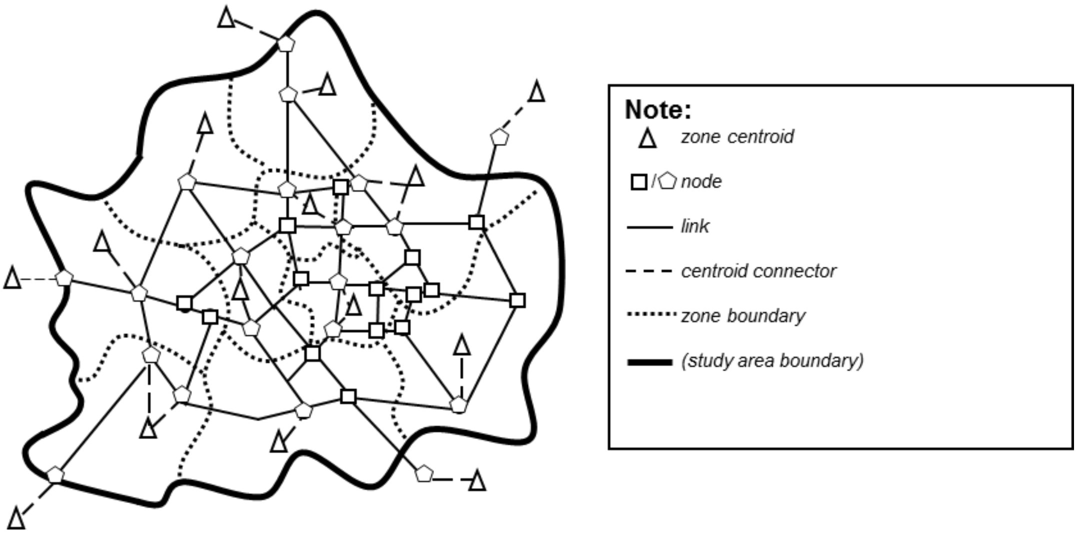


Figure 5 Road Network System Representation

In this study, every zone represented by 1 (one) centroid which was connected to the road network through centroid connector. **Table 2** shows zone number (code) and zone name. Internal zone is a zone which is located inside the road network (study area). External zone is a zone which is located outside the road network (study area).

Table 2 Zoning

No	Zone Number	Zone Name	Zone Type
1	903	Samalari	Internal
2	904	Seical	Internal
3	905	Buibau	Internal
4	906	Caibada	Internal
5	907	Buruma	Internal
6	908	Bahu	Internal
7	909	Tirilolo	Internal
8	910	Tricola	Internal
9	911	Vemasse	Internal
10	912	West Zone	External
11	913	South Zone	External
12	914	East Zone	External

Source: https://www.mof.gov.tl/about-the-ministry/statistics-indicators/sensus-fo-fila-fali/download-suco-reports/baucau-suco-reports/

2.4.3 Road Network System

Road network data model consists of primary arterial, primary collector, secondary arterial and secondary collector roads surrounding the study location or within Baucau Subdistrict. Based on zoning system, the road network is shown as **Figure 6** below.

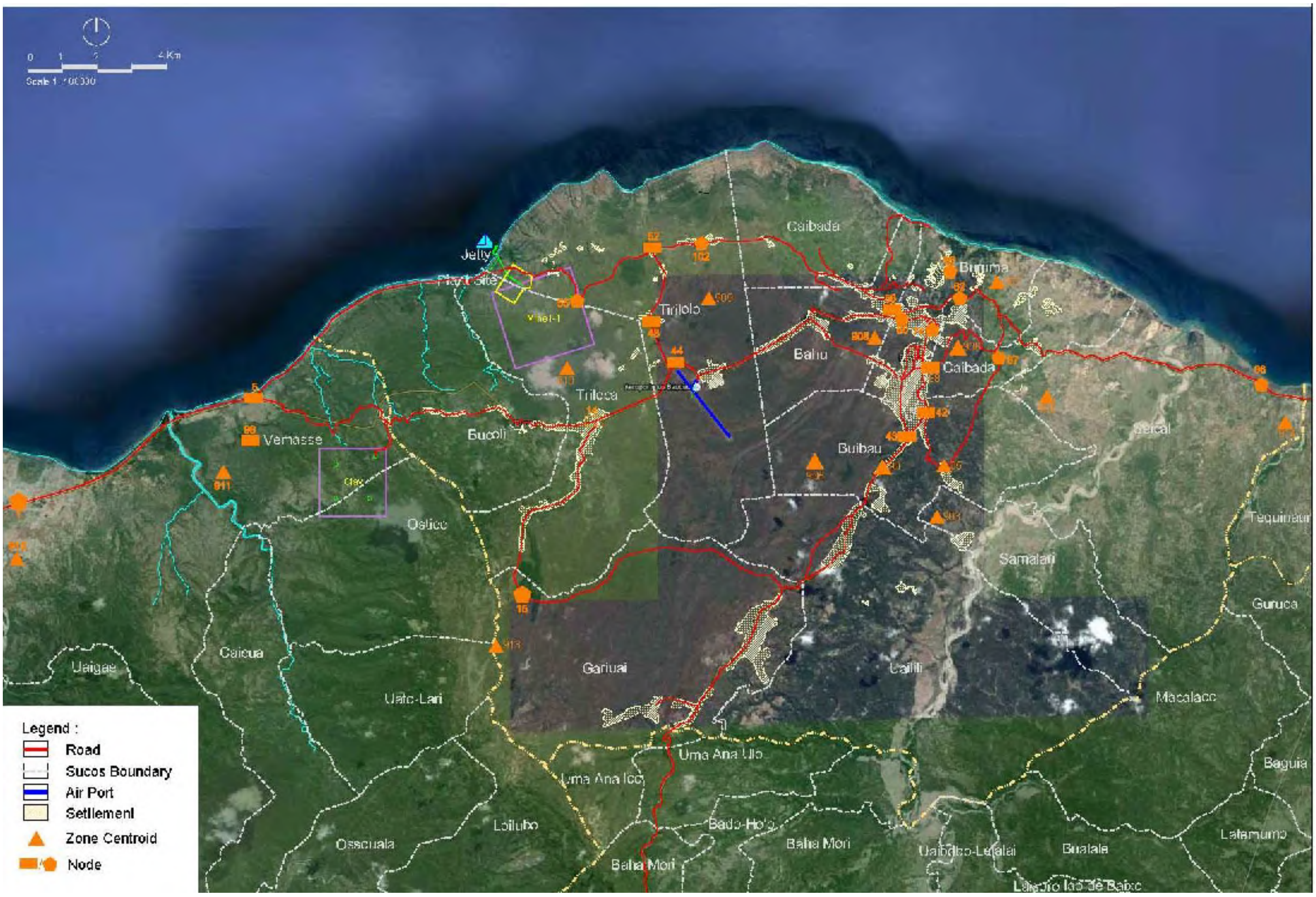


Figure 6 Existing Road Network System

Then, this road network is converted into model format and the configuration of road network of study location is shown in **Figure 7**.

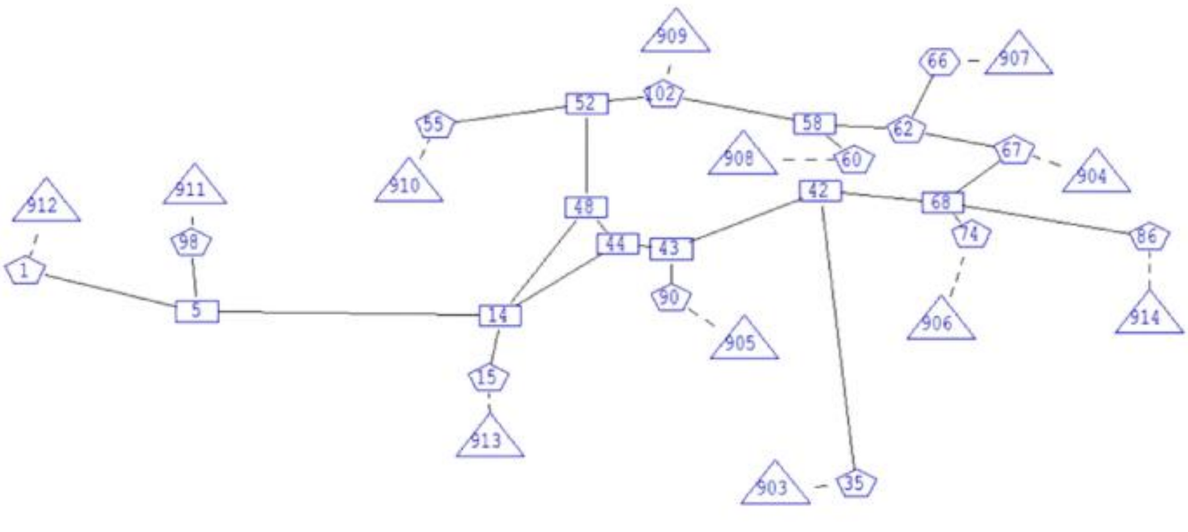


Figure 7 Model Format of Road Network System

2.4.4 Validation Model

R^2 of 0.7578 indicate that Origin–Destination matrix (trip matrix) prediction using ME2 can be representing more than 75.8% of traffic in the Baucau subdistrict. Trip matrix prediction model is fairly accurate to present trip demand pattern in the study area, so it can be used to predict future trip matrix.

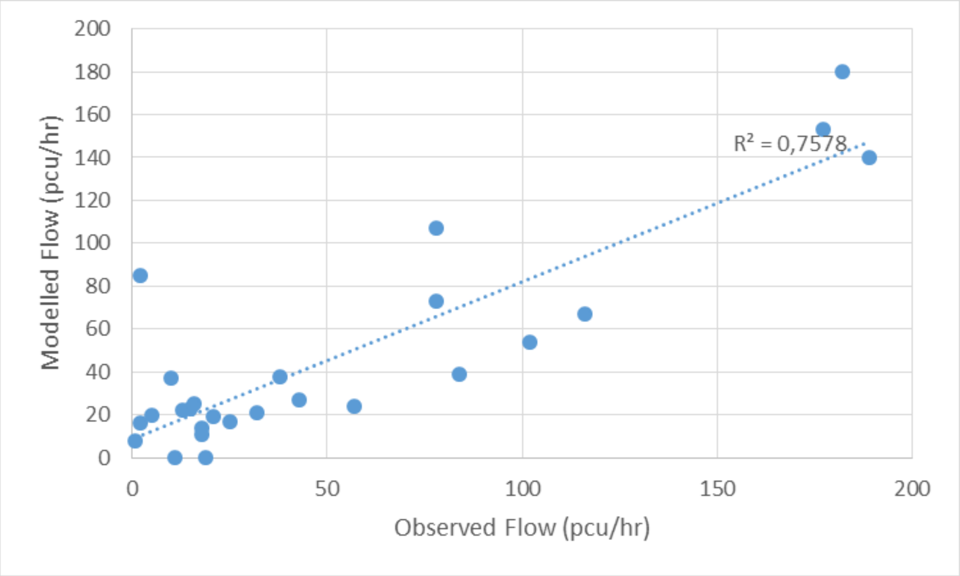


Figure 8 Validation Model

Table 3 Observed vs Model Speed (kph)

No	Segment	Speed (km/h)	
		Model	Observed
1	L1 (Triloca)	31.5	41
2	L2 (Tirilolo)	31,5	46
3	L3 (Lialailesu)	28,5	19
4	L4 (Wailacama)	69	NA

Table 4 Observed vs Model Flow (pcuph)

No	Name		Flow (pcuph)	
			Count	Model
1	TC 01	Dili-Baucau Kota Baru	78	63
2		Baucau Kota Baru-Dili	116	107
3		Baucau Kota Baru-Baucau Kota Lama	18	18
4		Baucau Kota Lama-Baucau Kota Baru	18	18
5		Baucau Kota Lama-Dili	25	23
6		Dili-Baucau Kota Lama	32	25
7	TC02	Baucau-Caisido	19	0
8		Dili-Caisido	15	13
9		Caisido-Dili	21	13

No	Name		Flow (pcuph)	
			Count	Model
10		Caisido-Baucau	11	0
11		Dili-Baucau	84	81
12		Baucau-Dili	177	170
13	TC 03	Dili-Baucau	78	77
14		Baucau-Dili	102	97
15	TC 04	Dili-Losp	182	50
16		Dili-Caibada	57	57
17		Dili-Flamboyan	43	43
18		Calibada-Losp	1	10
19		Calibada-Dili	38	38
20		Calibada-Flamboyan	2	22
21		Losp-Dili	189	189
22		Losp-Flamboyan	2	24
23		Losp-Calibada	5	18
24		Flamboyan-Dili	16	16
25		Flamboyan-Losp	10	62
26		Flamboyan-Calibada	13	52

3 TRAFFIC DATA

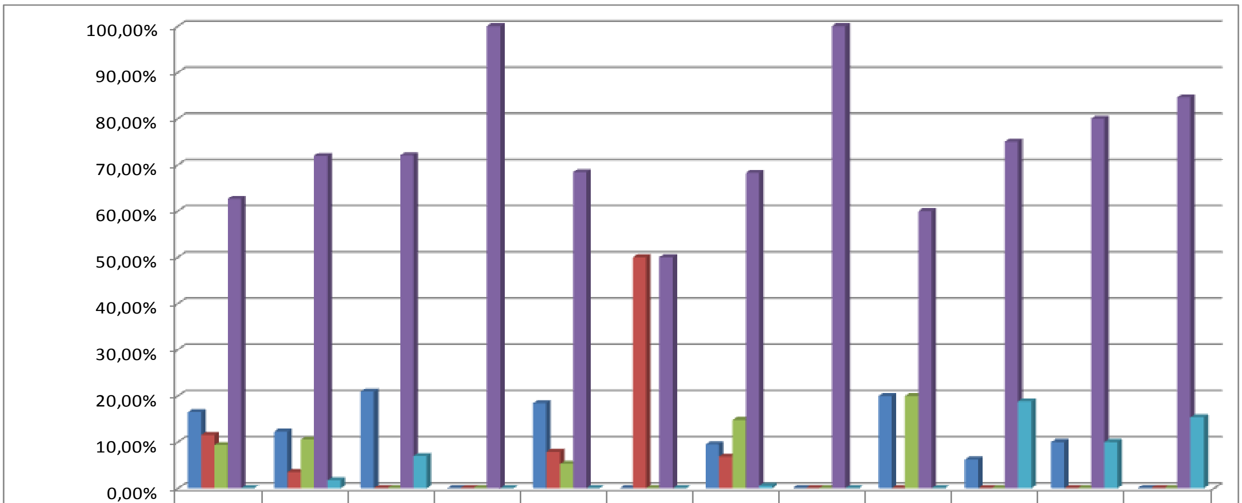
3.1 Road Network Traffic Condition

3.1.1 Traffic Counting Data

Data has been compiled and the result is shown in **Table 5** and **Figure 9**. It can be seen that the highest percentage of flow is motor cycle. Unmotorised vehicle is included in traffic flow calculation, but for further analysis using Indonesia Highway Capacity Manual (IHCM) it is excluded. It is assumed as side friction.

Table 5 Traffic Flow (pcuph)

Time	Dili-Baucau Kota Baru	Baucau Kota Baru-Baucau Kota Lama	Baucau Kota Baru-Dili	Baucau Kota Lama-Baucau Kota Baru	Baucau Kota Lama-Dili
7:00 - 7:15	32	68	0	0	32
7:15 - 7:30	44	32	12	12	8
7:30 - 7:45	64	44	0	0	28
7:45 - 8:00	60	64	8	8	32
8:00 - 8:15	60	64	20	20	28
8:15 - 8:30	44	44	16	16	24
8:30 - 8:45	20	48	4	4	12
8:45 - 9:00	76	72	8	8	28
Maksimum	76	72	20	20	32
12:00 - 12:15	40	56	8	8	12
12:15 - 12:30	36	56	0	0	4
12:30 - 12:45	60	48	16	16	8
12:45 - 13:00	20	48	16	16	16
13:00 - 13:15	20	72	8	8	4
13:15 - 13:30	20	52	8	8	28
13:30 - 13:45	56	72	4	4	16
13:45 - 14:00	60	60	12	12	12
Maksimum	60	56	16	16	16
16:00 - 16:15	32	24	4	4	32
16:15 - 16:30	44	32	8	8	32
16:30 - 16:45	80	48	8	8	16
16:45 - 17:00	8	48	0	0	16
17:00 - 17:15	40	12	16	16	20
17:15 - 17:30	60	32	4	4	24
17:30 - 17:45	76	24	28	28	24
17:45 - 18:00	56	28	4	4	12
Maksimum	80	48	28	28	32



	Dili-Losp	Dili-Caibada	Dili-Flamboyan	Calibada-Losp	Calibada-Dili	Calibada-Flamboyan	Losp-Dili	Losp-Flamboyan	Losp-Calibada	Flamboyan-Dili	Flamboyan-Losp	Flamboyan-Calibada
Car	16,48%	12,28%	20,93%	0,00%	18,42%	0,00%	9,52%	0,00%	20,00%	6,25%	10,00%	0,00%
Bus	11,54%	3,51%	0,00%	0,00%	7,89%	50,00%	6,88%	0,00%	0,00%	0,00%	0,00%	0,00%
Truck	9,34%	10,53%	0,00%	0,00%	5,26%	0,00%	14,81%	0,00%	20,00%	0,00%	0,00%	0,00%
Motorcycle	62,64%	71,93%	72,09%	100,00%	68,42%	50,00%	68,25%	100,00%	60,00%	75,00%	80,00%	84,62%
Unmotorised	0,00%	1,75%	6,98%	0,00%	0,00%	0,00%	0,53%	0,00%	0,00%	18,75%	10,00%	15,38%

Figure 9 Traffic Flow as Percentage by Vehicle Types

3.1.2 Speed Data

Spot speed was conducted in 4 locations **L1, L2, L3, and TC03** (see **Figure 3**). Approximately 20 speed data has been collected for each location and then space mean speed is calculated. The example of data and calculation of location L1 is shown in **Table 6**.

Table 6 Spot Speed Data

Vehicle No.	Travel Time (second)	Vehicle No.	Travel Time (second)
1	8.43	11	6.57
2	6.66	12	5.95
3	8.04	13	6.39
4	8.75	14	6.11
5	6.51	15	7.88
6	7.45	16	6.77
7	7.81	17	6.18
8	6.68	18	7.25
9	7.86	19	6.49
10	7.41	20	6.93

Location	L1
Segment length (m)	80
Average Travel Time (sec)	7.106
Space mean speed (km/h)	40.53

3.1.3 Road Network Condition

Traffic impact caused by new activities will be experienced by a road network surrounding Clinker Plant and Clay Deposit (see red line in **Figure 21**). Existing condition of all road in the network are lack of road furniture, i.e. road lighting, road marking, road sign, and road barrier. Road furniture was only found closed to the bridge, consist of bridge warning sign (unclear) cover with plantation, directional sign, maximum axle load sign, horizontal curve sign, and road barrier (only one side), see **Figure 10**.

Figure 11 shows existing road condition which has 5 meter wide, unpaved shoulder and some shoulder are covered by plantation, and no side ditch. Because road width is relatively narrow, it is difficult if two vehicles pass through at the same time. Generally, arterial road are paved by asphalt, but collector road are remained unpaved. Some points at the segment of roads were found damaged or potholes, either small or big. **Figure 11** shows road geometric are in substandard design, it is indicated by:

- Small radii curvatures
- Short lateral clearance
- High gradient (steep -upgrade and -downgrade)

All the intersections in the road network are uncontrolled intersection, no road marking, no road sign (see **Figure 12**).

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Figure 10 Road Furnitures in Existing Road

Figure 11 Road Network Condition

Figure 12 Uncontrolled Intersection at the Study Area

3.1.4 Coastal Road

Coastal road is located western part of Clinker Plant. A large portion of the coastal road is unpaved and only suitable for 4x4 (see **Figure 13**). The coastal road passing estuary is unpassable at high-tide. But, a few portion of the coastal road (eastern part) is already paved and in good condition. The intersection between Dili-Baucau road and coastal road is a T-junction and it is located in Caravela.

Figure 13 Coastal Road Passing the Estuary

3.2 Road Network Traffic Performance

3.2.1 Trip Attraction and Generation Model

Trip Attraction and Generation Model year 2015 is developed from traffic counting data and then using ME2 method trip attraction and trip generation for each zone centroid will be found and is represented as Origin Destination Matrix (O-D matrix). Trip Attraction and trip Generation is summation of row and column of O-D matrix and it is figured out as barchart as seen in **Figure 14.**

It was shown from the figure that each zone centroid attracts a number of vehicles (green bar) and generate a number of vehicles (purple bar). Zone centroids in Baucau city attract and generate more vehicle than zone centroid in rural areas (non-developed areas). Zone centroid 905 (Buibau), 913 (South zone), and 914 (East zone) are attract more trip than generate, whereas others are attracting fewer trips than generate trip.

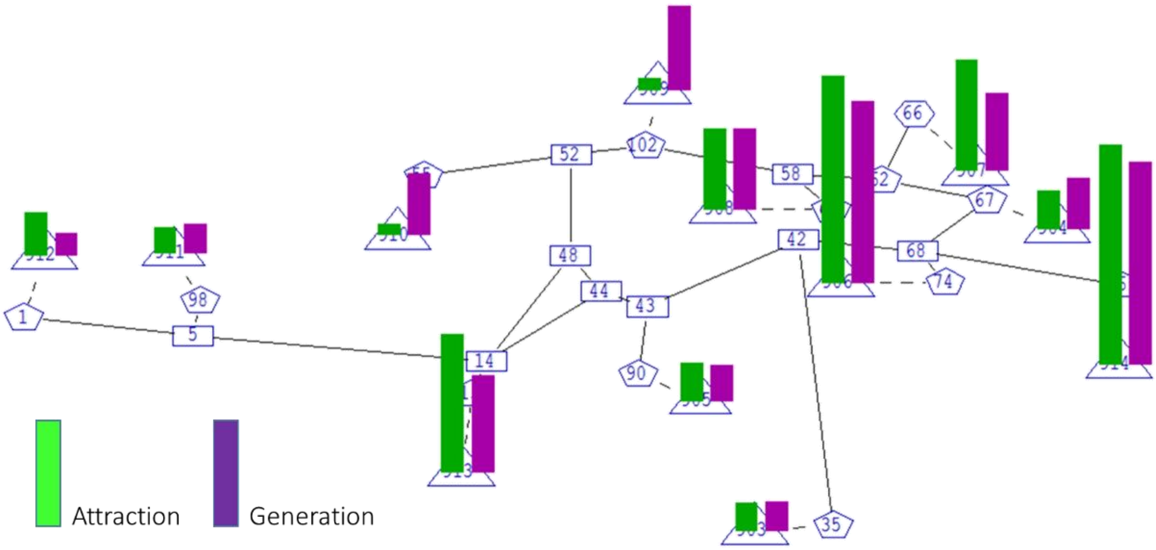


Figure 14 Trip Attraction and Generation

3.2.2 Trip Distribution Model

Trip distribution model is developed to distribute trip generation and trip attraction from and to each zone based on accessibility level for each zone-pair. Trip distribution matrix can be represented as desire line, which is the trip value between zone and the thickness of the line representing the relative value. Trip distribution (in pcuph), which is representing as desire line, of study area year 2015 can be seen in **Figure 15.**

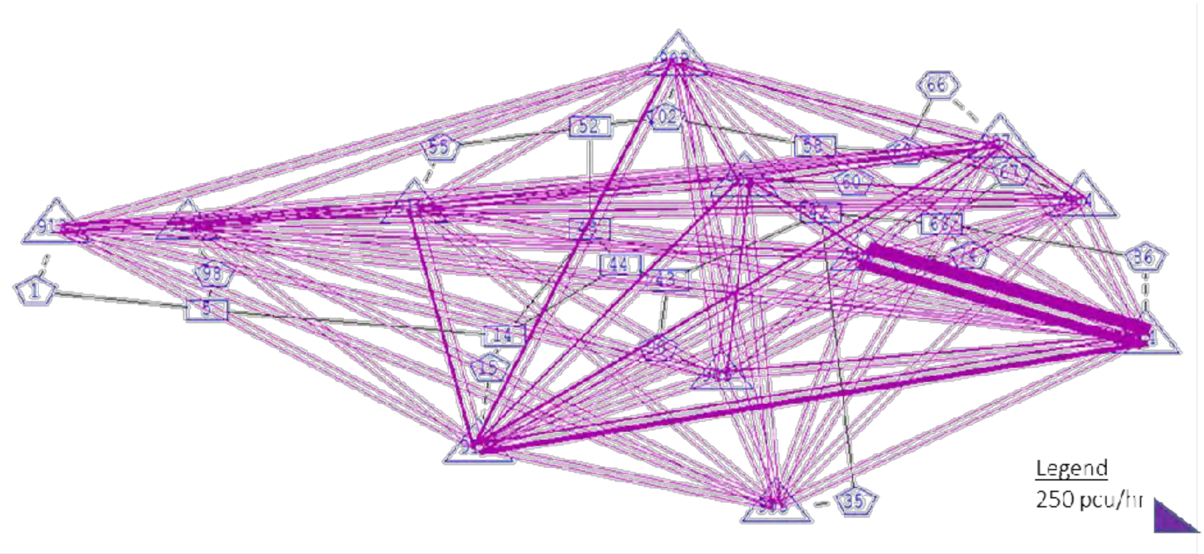


Figure 15 Desire Line

3.2.3 Trip Assignment Model

The main purpose of trip assignment is to identify which routes will be used by road user from origin to destination and to know the number of trip using each link in the road network. Factors influencing trip assignment are characteristic of study area, alternate routes, road user behavior, and traffic jam.

In this study all-or-nothing method is chosen as assignment model and the result of traffic assignment in the road network can be seen in **Figure 16**.

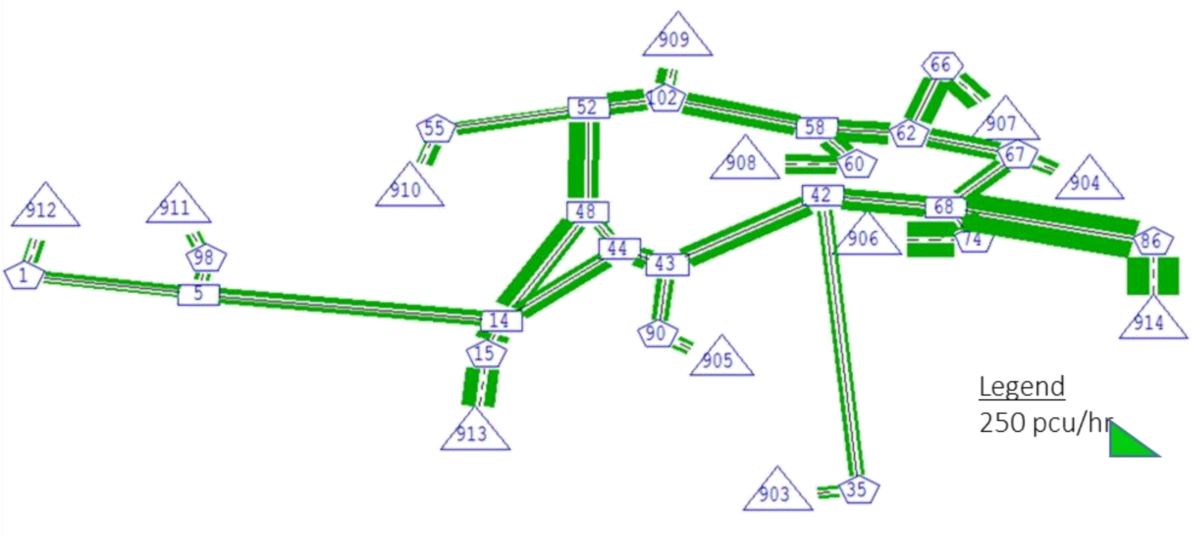


Figure 16 Trip Assignment

Trip assignment can also be presented in tabular. It was shown that the highest trip on link is occurred in link between zone 86 (external zone) and zone 68 (Caibada) which is 245 pcuph. The second highest trip distribution is occurred in link between zone 68 to zone 86, which is 225 pcuph. This resulting total trip on this road is 470 pcuph.

Table 7 Existing Link Flow Condition

Origin	Destination	Flow (pcuph)	Origin	Destination	Flow (pcuph)	Origin	Destination	Flow (pcuph)
1	5	47	44	14	102	60	58	90
5	1	24	44	43	76	62	66	87
5	14	73	44	48	19	62	67	88
5	98	32	48	14	39	62	58	124
5	1	24	48	44	23	66	62	124
14	44	53	48	52	172	67	68	62
14	48	153	48	14	39	67	62	77
14	5	54	52	48	62	68	42	128
14	15	107	52	55	67	68	67	66
15	14	153	52	102	135	68	74	203
35	42	31	52	55	67	68	86	225
42	35	32	52	102	135	74	68	231
42	43	121	55	52	11	86	68	245
42	68	84	58	60	89	90	43	42
43	42	78	58	62	98	98	5	28
43	44	121	58	102	122	102	52	81
43	90	40	58	62	98	102	58	95

3.2.4 Traffic Performance

The road network is classified into two functional classes, i.e. arterial and collector roads. Road width varies from 4 to 5 meters, resulting a road capacity of 900 pcuph and 1,227 pcuph respectively.

Volume capacity ratio between 0.5 - 0.7 only occurred on link between node 86 and node 68 and node 74 to node 68 (see **Figure 17**) and volume capacity ratio between 0.2 – 0.5 occured only on several link as shown as red line in **Figure 18**. It can be concluded that traffic demand for existing condition is still far below road capacity. The rest of the links are experienced volume capacity ratio less than 0.2.

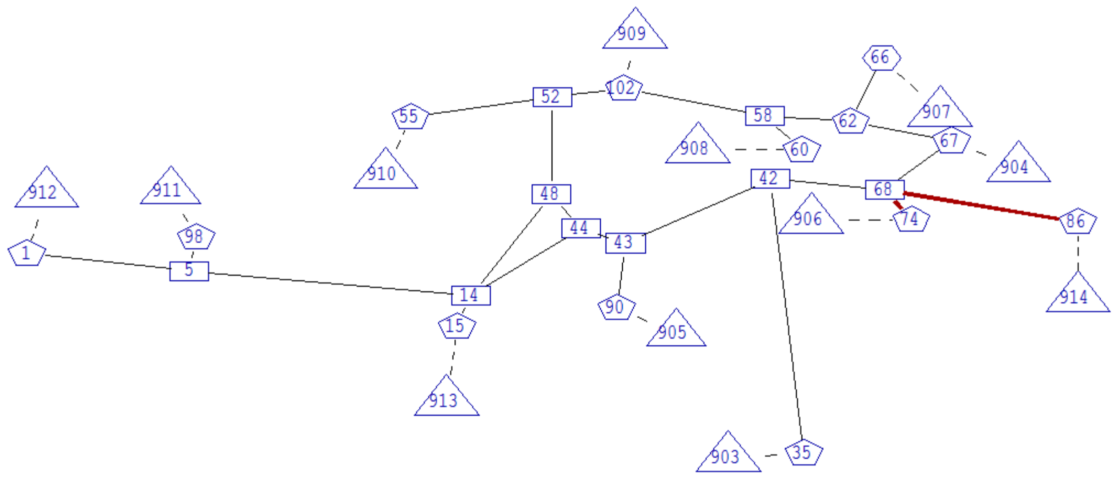


Figure 17 Volume Capacity Ratio 0.5 - 0.7

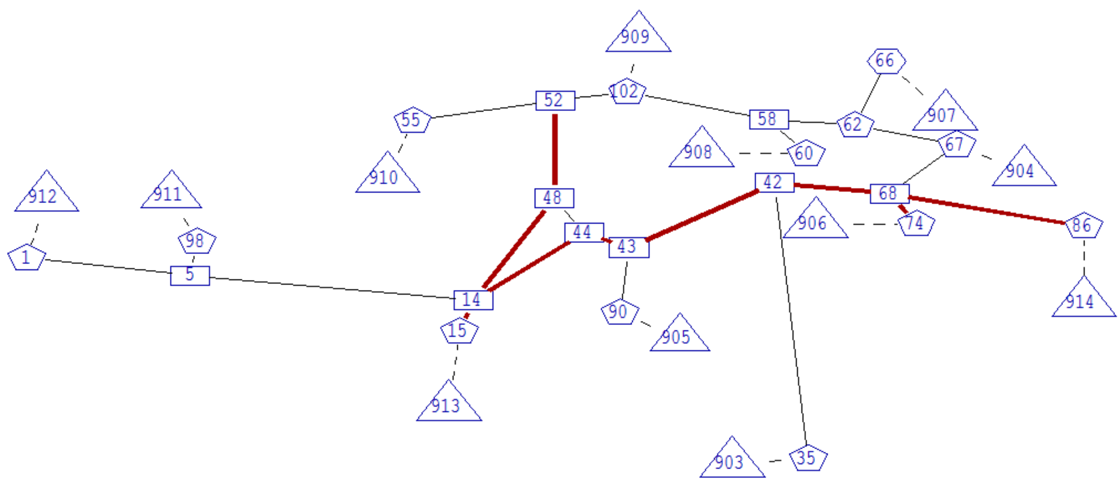
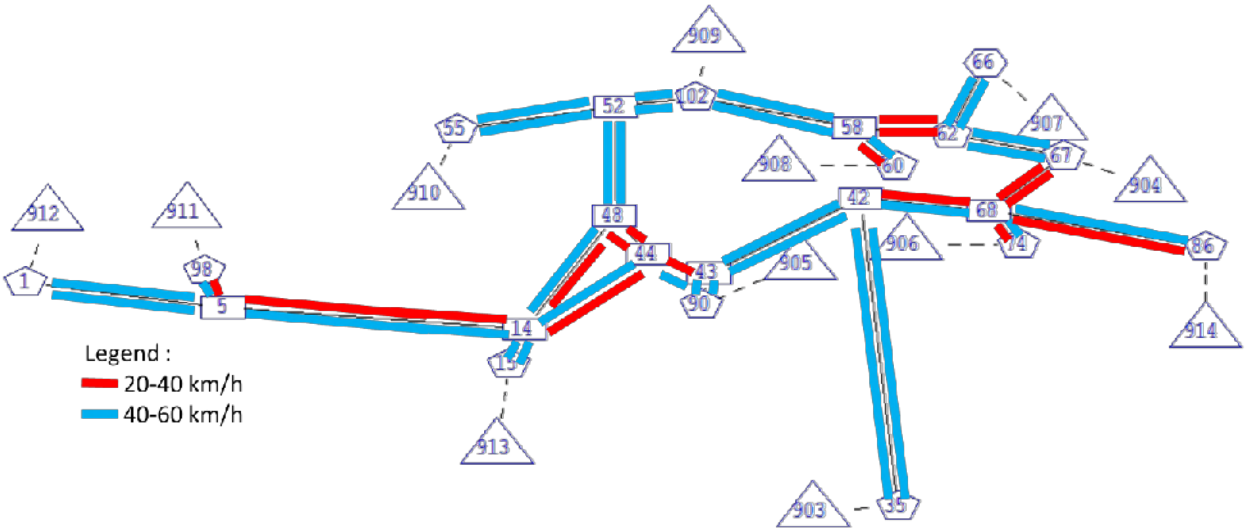


Figure 18 Volume Capacity Ratio between 0.2 – 0.5

The blue line in **Figure 19** shows the road with time mean speed at the existing condition. There is a link road that experience time mean speed less than 20 kmph, but the link is short and occur around node 68. The rest of the roads in the studied road network experience time mean speed between 40-60 kmph. It can be concluded that overall time mean speed around project area are still in a good condition.



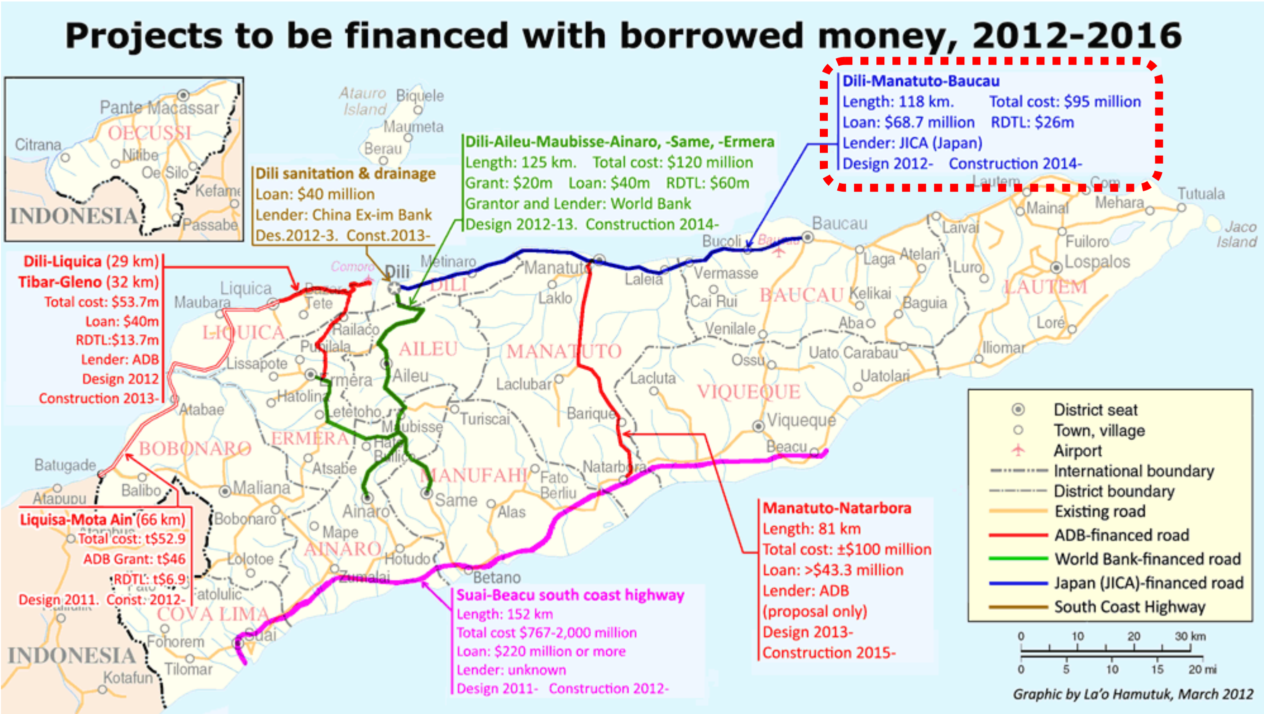
Note : speed from node 5 to 14 is shown in blue colour, whereas from node 14 to node 5 speed is noted as red colour

Figure 19 Speed at the existing condition

3.3 Regional Transport Development Plan

During survey implementation, BITA had met with the officers of MPoW (Ministry of Public of Work) and JICA representative on June 1, 2015. The meeting discussed the government plan for road improvement between Dili – Baucau. During discussion with the authorized officers, BITA did not obtained the report document as this report was being discussed by relevant agencies. BITA just got the brief information on the length and width of the proposed road which will be improved.

The Government of the Democratic Republic of Timor-Leste (hereinafter referred to as GOTL) has received a Loan from Japan International Cooperation Agency (JICA) toward the cost of the National Road No. 1 Upgrading Project. This Project is to make the National Road No.1 passable in safe throughout a year in any weather situation by upgrading the 118 km road from capital city Dili to the second largest city, Baucau. The project involves the widening of the current 3.2 - 4.5 m road to 6.0 m width asphaltic concrete pavement. Improvement includes drainage and slope protection works, construction of 7 new bridges and rehabilitation of existing bridges.



Source : http://www.laohamutuk.org

Figure 20 Road Projects in TimorLeste

4 IMPACT ASSESSMENT

4.1 Construction Phase

It is predicted that there will be an additional traffic flow due to the following activities:

- Mobilisation of heavy vehicle and materials from Dili to clay deposit and clinker plant areas.
- Mobilisation of construction workers.

To analyze the magnitude of impacts, the assumption has been developed based on professional judgement and analogical approach.

During construction phase of Clinker Plant, it is assumed that there will be 1,000 persons per day from Baucau work in both clay deposit (zone 915) and Clinker Plant (zone 916). Medium bus with a capacity of 20 passengers will be provided to serve workers. It causes additional daily traffic flow on an existing road network during construction. In consequence, there will be an additional traffic flow to and from clay deposit and Clinker Plant of 18 pcuph and 102 pcuph respectively (see **Table 8**).

Additional traffic flow also comes from daily mobillisation of heavy vehicle transporting construction materials to clay deposit (4 trucks) and Clinker Plant (7 trucks). Accordingly, there will be additional traffic flow due to transportation of construction materials, i.e. 26 pcuph.

Table 8 Additional Traffic Flow

Origin - Destination	Vehicle Type	pcu value	Additional Traffic Flow (pcuph)	
			Construction Phase	Operation Phase
Clay Deposit and Clinker plant	MHV	2.4	26	10
Baucau city - Clinker plant (85%)	MB	2.4	102	71
Baucau city - clay deposit (15%)	MB	2.4	18	13
Baucau – Dili (Finished Product)	MHV	2.4		12

Source: IHCM (1997)
Assumption: Rolling terrain and Total traffic flow = 650 vph

Volume capacity ratio and time mean speed for construction phase can be seen in **Figure 21 to 23**. It was shown that traffic performance during construction will be worse compare with an existing condition (do nothing). It can be seen in **Figure 21** that volume capacity ratio greater than 0.5 is occurred on several links (node 48 – 52 – 55). **Figure 23** shows only three short links experience speed less than 20 km/h (node 5 – 103; node 44 – 48; node 52 - 102).

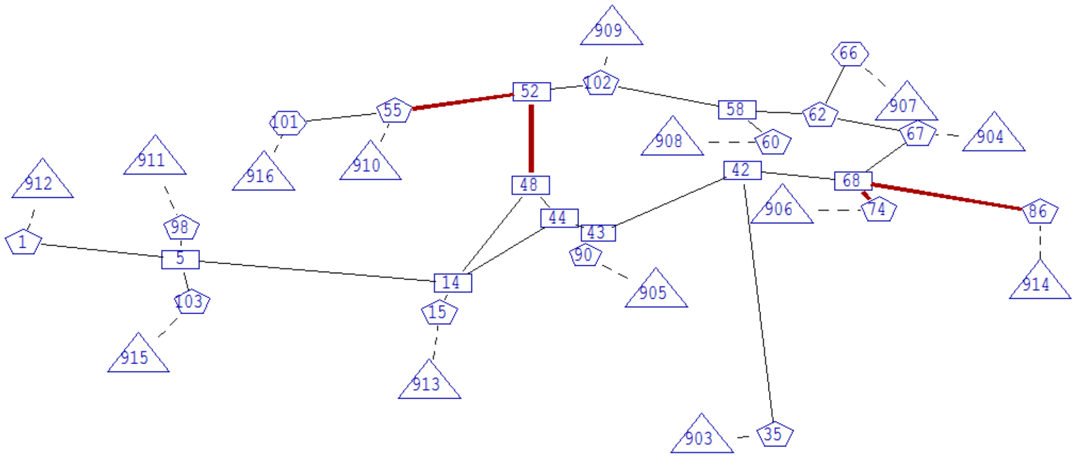


Figure 21 Volume Capacity Ratio between 0.5 – 0.7

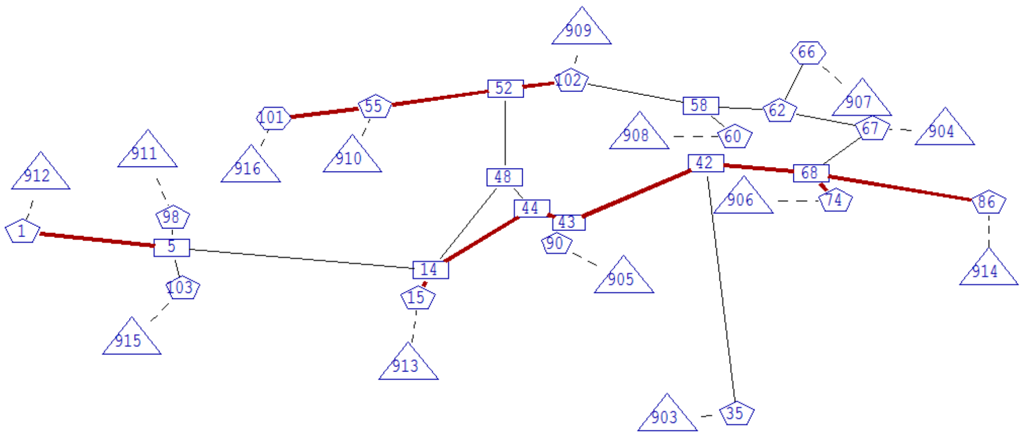
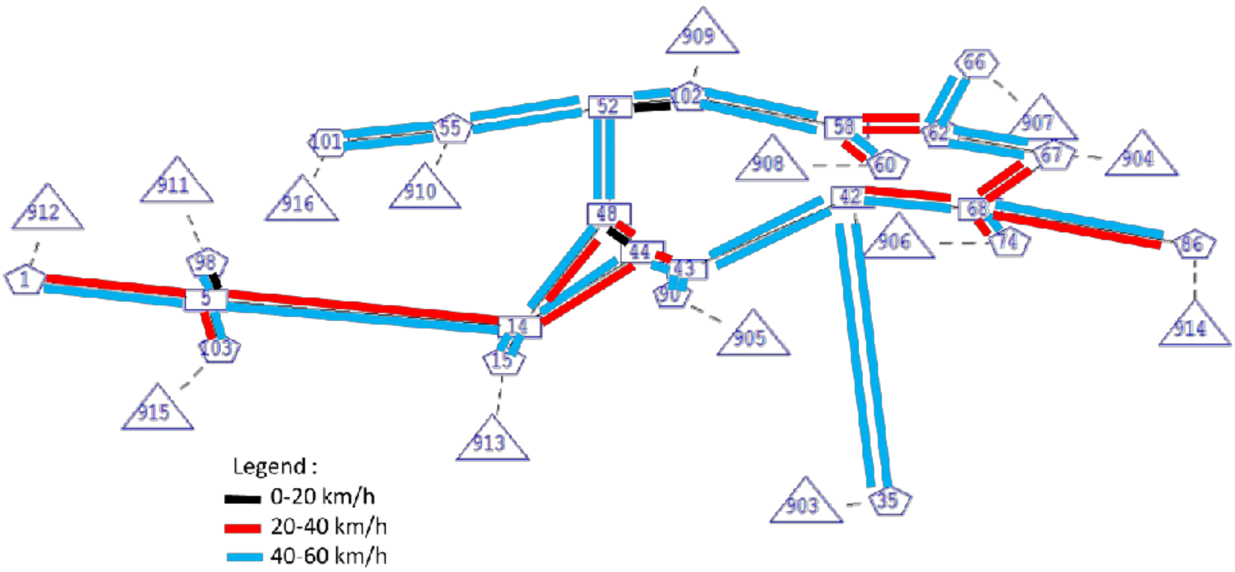


Figure 22 Volume Capacity Ratio between 0.2 – 0.5



Note : speed from node 5 to 14 is shown in blue colour, whereas from node 14 to node 5 speed is noted as red colour.

Figure 23 Speed less than 20 km/h

A v/c ratio over 1.0 indicates the road or intersection is over-capacity; a v/c ratio under 1.0 indicates there is still room to accommodate additional vehicles. IHCM (Indonesian Highway Capacity Manual) recommend v/c ratio during peak hours for design year not exceed 0.75. According to this standard, road networks performance during construction phase is in good condition.

4.2 Operation Phase

During operation phase there will be a generated traffic caused by transportation activities in clay deposit and Clinker Plant, and this will caused traffic impact on road network.

A. Transportation of Clay Material to Clinker Plant

It is assumed that clay (0.41 mio tonnes/year) will be transported from quarry to Plant using a dump truck with a capacity of 25 tonnes. Accordingly, it could generate approx. 4 truck trips per hour (330 days, 12-hours per day), so there will be additional traffic flow of 10 pcuph.

Clay transportation is planned to use three alternative routes (see **Figure 24**):

1) From clay deposit turn right, then using an existing road,
2) From clay deposit turn left until T-junction, then continue to use a coastal road, and
3) Built a new road direct from clay deposit to the coastal road, and then continue to clinker plant.

Figure 24 Alternative Routes

Alternative 1: Existing Road Network

Figure 25 shows links which has volume capacity ratio between 0.2 - 0.5 are links between node 101 – 55 – 52 – 102 and node 14 – 44 – 43 - 42 – 68 – 86. **Figure 26** shows only one link (node 44 – 48) experienced speed less than 20 km/h.

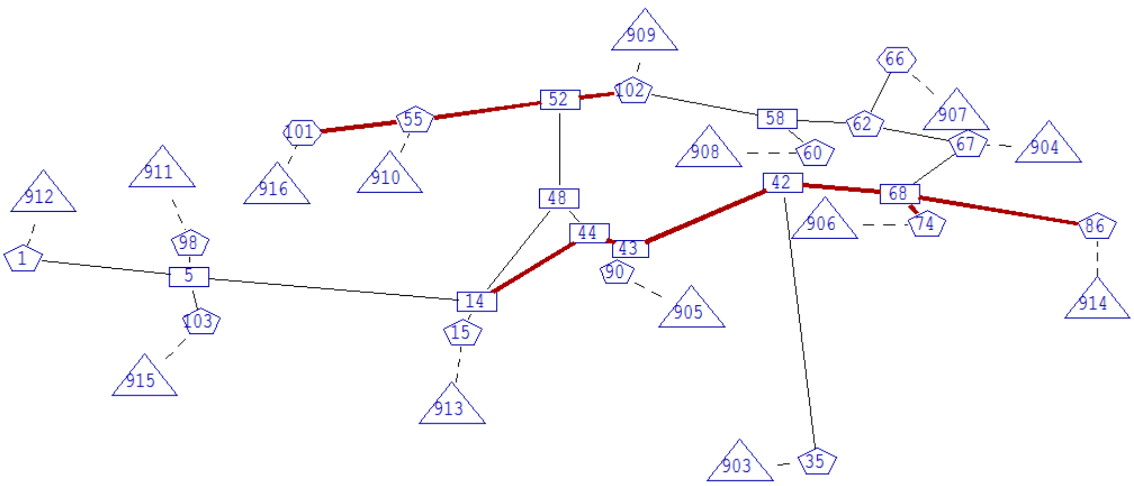
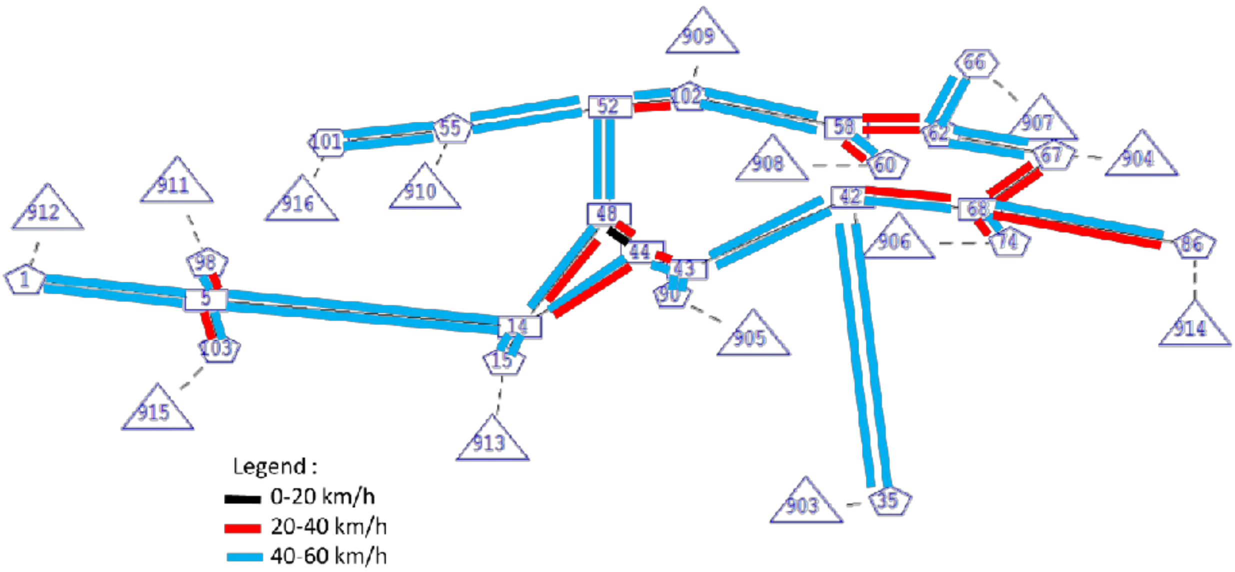


Figure 25 Volume Capacity Ratio between 0.2 – 0.5



Note : speed from node 14 to 44 is shown in red colour, whereas from node 44 to node 14 speed is noted as blue colour.

Figure 26 Speed using Existing Road

Alternative 2: Using Coastal Road

Figure below shows only several links (node 5 – 104; node 14 – 48 – 52 – 102; node 14 - 44 – 43 – 42 – 68 – 86; and node 68 – 74) has volume capacity ratio between 0.2 - 0.5 and the rest experienced volume capacity ratio less than 0.2. None of the link has speed lees than 20 km/h.

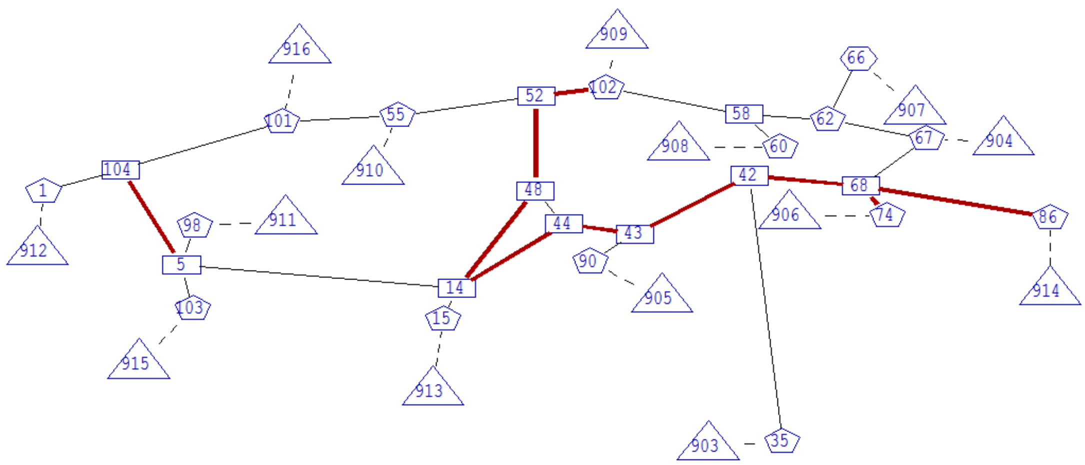
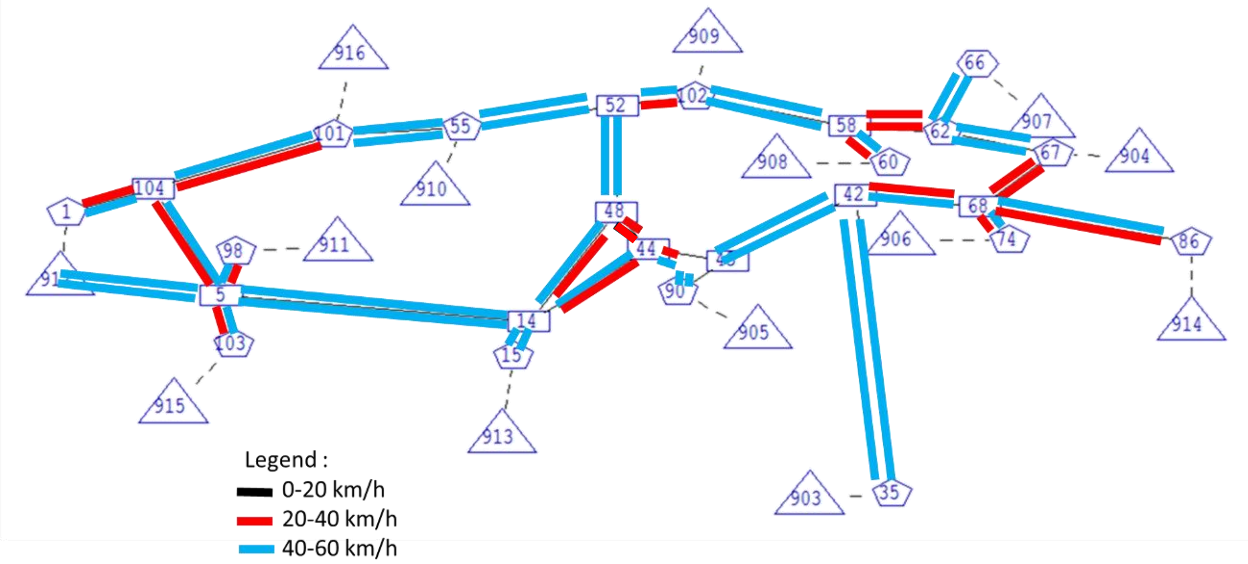


Figure 27 Volume Capacity Ratio between 0.2 – 0.5



Note : speed from node 14 to 44 is shown in red colour, whereas from node 44 to node 14 speed is noted as blue colour.

Figure 28 Speed using Coastal Road

Alternative 3: New Road

Links from node 1 – 5 – 104, node 14 – 48 – 52, node 14 – 44 – 43 – 42 – 68 – 86, and node 68 – 74 have volume capacity ratio between 0.2 - 0.5 (see Figure 27). None of the link has speed lees than 20 km/h.

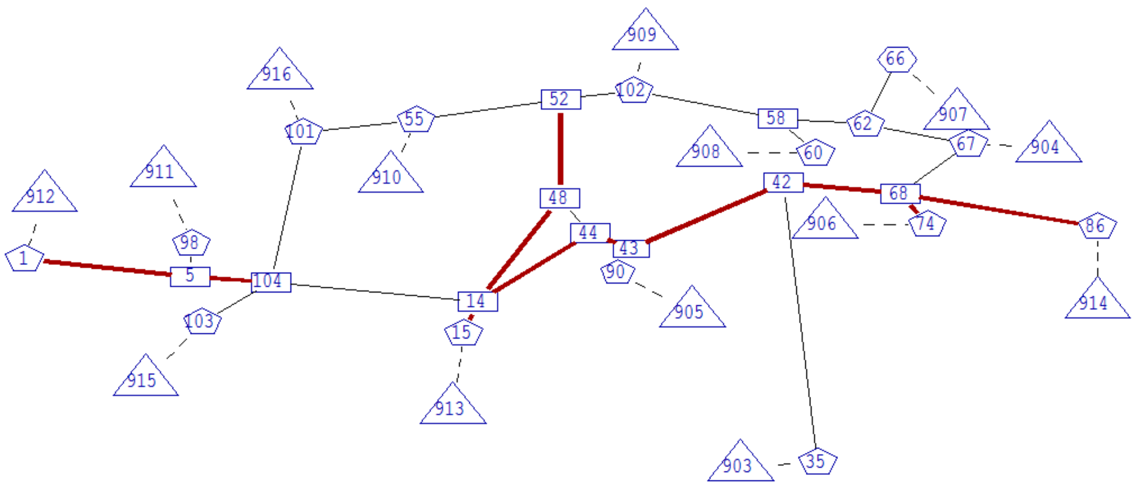
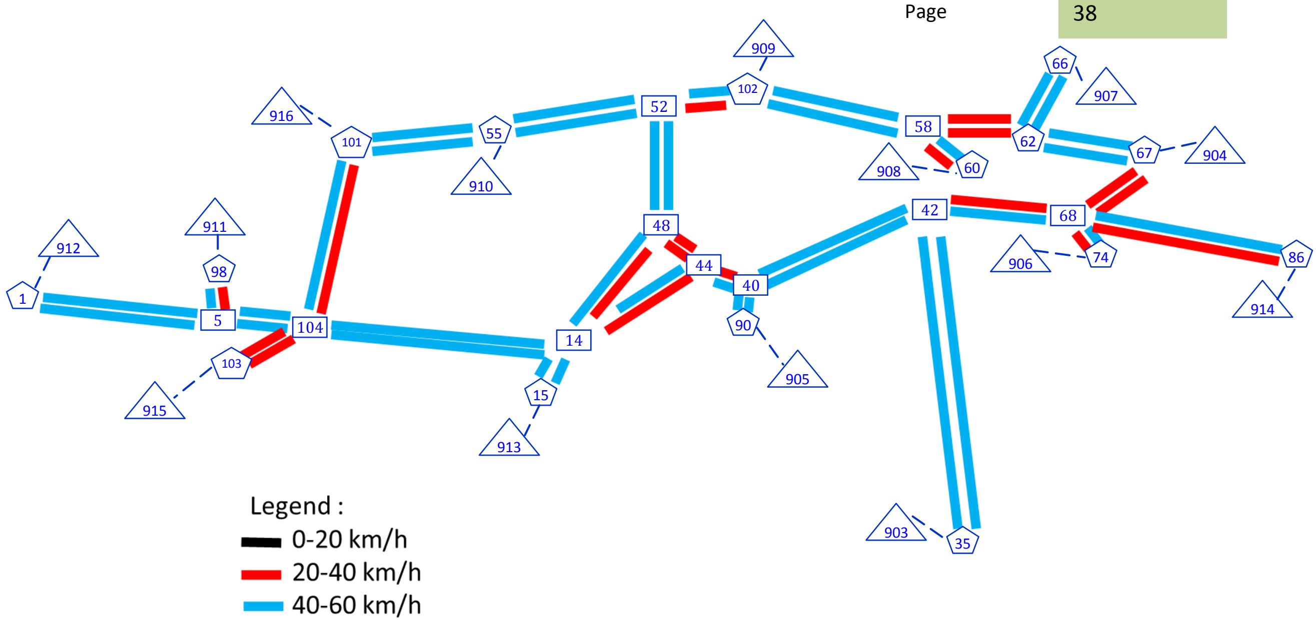


Figure 29 Volume Capacity Ratio between 0.2 – 0.5



Note : speed from node 14 to 44 is shown in red colour, whereas from node 44 to node 14 speed is noted as blue colour.

Figure 30 Speed using a New Road

A v/c ratio over 1.0 indicates the road or intersection is over-capacity; a v/c ratio under 1.0 indicates there is still room to accommodate additional vehicles. IHCM recommend v/c ratio during peak hours for design year not exceed 0.75. According to this standard, road networks performance during clay transportation is in good condition.

B. Transportation of Finished Product

During operation phase, the finished product will be delivered from Plant (Baucau) to local market, i.e. Dili. Up to 0.5 million tonnes per annum of finished product will be transported using trucks to Dili. If using 25-ton trucks to transport, it could generate approx. 5 truck trips per hour (330 days, 12-hours per day), so there will be additional traffic flow of 12 pcuph.

C. Transportation of Workers

There will be 700 persons per day work during operation phase. It is assumed that all the worker stay in Baucau city, so they will commute from the city to clinker plant and from the city to clay deposit. All workers will be transported by medium bus with a capacity of 20 passengers. It is assumed that 85 % of worker work in Clinker Plant and the other 15 % work in clay deposit, so there will be additional traffic from the city to clay deposit of 13 pcuph and from the city to Clinker Plant of 71 pcuph.

During operation phase, all road networks within the study area are in a good traffic performance. Most road link experience low volume capacity ratio and average mean speed higher than 20 km/h.

D. Road Development Plan

The Government of the Democratic Republic of Timor-Leste (hereinafter referred to as GOTL) has received a Loan from Japan International Cooperation Agency (JICA) toward the cost of the National Road No. 1 Upgrading Project. This Project is to make the National Road No.1 passable in safe throughout a year in any weather situation by upgrading the 118 km road from capital city Dili to the second largest city, Baucau. The project involves the widening of the current 3.2 - 4.5 m road to 6.0 m width asphaltic concrete pavement.

By implementing the above project, it is believed that the road network will be in good performance as more vehicles could be accommodated. Assuming that the volume value remains the same, then the volume capacity ratio (v/c) value could be less than 0.75 as the value of the capacity (c) will be increasing due to road widening. Therefore, the road networks will provide better service.

4.3 Intersection Performance

Intersection is most critical one in the network and it should be designed with a proper type of control. Intersection which is indicated having heavy traffic will be analysed further.

During construction phase and operation phase for alternative 1 and 2, there will be two intersections should be taken into account, i.e Intersection A and B, and for alternative 3 of operation phase there will be additional intersection, i.e. C (see **Figure 24**). Those three intersections are controlled by unsignalised intersection without priority rules, traffic sign, and traffic marking. Using Indonesian Capacity Manual (IHCM), traffic performance can be calculated and the results are presented in **Table 9**. Maximum traffic flow (909 pcuph) occurred in B intersection during construction phase, this is due to mobilization of construction heavy vehicle. All vehicles experience low delay, where the maximum delay (9.16 sec/pcu) is occurred in A intersection for alternative 1 of operation phase.

The road to Plant location, the road from Baucau, and the road from Dili are converging in intersection B. So the traffic performance can be seen in **Table 9**. Whereas, the intersection between existing road and coastal road in Caravela is similar to intersection A in term of traffic flow by movement.

Table 9 Intersection Delay

	Flow (pcuphr)			Delay (sec/pcu)		
	A	B	C	A	B	C
Existing Condition	129	367	NA	6.04	6.39	NA
Construction Phase	767	909	NA	7.32	7.59	NA
Operation Phase Alt 1 : Existing Road	487	781	NA	9.16	7.20	NA
Operation Phase Alt 2 : Coastal Road	382	328	NA	7.13	5.56	NA
Operation Phase Alt 3 : New Road	290	300	553	5.00	6.48	5.85

Traffic performance on Intersection can also measured by travel time. During construction phase, travel time is 32 minutes. While during operation, alternative 3 has the lowest travel time, i.e. 15 minutes.

Table 10 Travel Time from Clay Deposit to Cliker Plant

	Travel Times (minutes)	Speed (km/hr)	Distance (km)
Construction Phase	32	42.21	23
Operation Phase Alt 1 : Existing Road	31	43.58	23
Operation Phase	21	35.25	13

	Travel Times (minutes)	Speed (km/hr)	Distance (km)
Alt 2 : Coastal Road			
Operation Phase Alt 3 : New Road	15	37.99	9

5 IMPACT MITIGATION

To reduce the impact of traffic both in the construction and the operation phases, managing traffic is essential to providing a safe construction and operation activities. Traffic can include cars, utilities, delivery trucks, excavators, etc. The safe construction and operation activities can be achieved by careful planning and by controlling vehicle operations.

The traffic management plan should be regularly monitored and reviewed to ensure it is effective and to take into account any changes during construction and operation activities. All workers should be familiar with the traffic management plan and receive sufficient information, instruction, training, and supervision. The followings are impact mitigation plan during construction and operation activities:

5.1 Mitigation at Workplace

A. Minimising Vehicle Movements

Good planning can help to minimise vehicle movement around a workplace. To limit the number of vehicles at a workplace:

- Provide vehicle parking for workers and visitors away from the work area;
- Control entry to the work area;
- Plan storage areas so that delivery vehicles do not have to cross the site.

B. Vehicles Reversing

The need for vehicles to reverse should be avoided where possible as reversing is a major cause of fatal accidents. One-way systems can reduce the risk, especially in storage areas. A turning circle could be installed so that vehicles can turn without reversing. Where it is necessary for vehicles to reverse:

- Use reversing sensors and mirrors and warning devices such as reversing alarms;
- Ensure drivers have another person to direct them before reversing if they cannot see clearly behind. The driver should maintain visual contact with the person directing them and signallers should wear high visibility clothing;
- Ensure workers and other people are familiar with reversing areas and reversing areas are clearly marked.

C. Traffic Signs

Prominently display clear warning signs in relevant, well lit areas to remind persons of the traffic management hazards and requirements. Excavations area should be clearly signed.

Traffic routes should be clearly sign posted to indicate restricted parking, visitor parking, headroom, speed limits, vehicle movement, key site areas and other route hazards. Standard road signs should be used where possible and speed limits should be implemented and enforced.

5.2 Mitigation along the Route

5.2.1 Construction Phase

A. Minimising Road Damage

The construction activities will potentially damage the local/public roads surrounding the project area due to operation of the heavy vehicles which has high axle load. Therefore, in order to ensure that roads will support the construction activities, be responsible for their own damage, and maintain positive relationships with the local community. The overlaying of existing roads need to be undertaken minimum once a year, in particular roads which are used for heavy vehicle mobilization.

B. Traffic Signs

Standard road signs should be used where possible and speed limits should be implemented and enforced. Warning signs and sight mirrors shall be installed at appropriate places on the roads.

C. Road Widening

During construction, heavy vehicle movement occurred only twice, i.e. mobilisation and demobilisation. It is therefore the road widening will not be required; eventhough the road width within the study area is relatively narrow to support the heavy vehicle movements.

D. Heavy Vehicle and Trucks

- The transport and movement of equipment (trucks) should be limited to working hours only.
- Heavy equipment should be transported during early morning with appropriate pilotage.
- The use of flagmen should be employed to regulate trucks entering and exiting the access roads to the highway or at the junction (if necessary).

5.2.2 Operation Phase

A. Minimising Road Damage

The overlaying of existing roads between clay deposit and clinker plant need to be undertaken as a routine maintenance. The overlaying of roads should be undertaken in accordance with the road design.

B. Traffic Signs

Standard road signs should be used where possible and speed limits should be implemented and enforced. Warning signs and sight mirrors shall be installed at appropriate places on the roads.

Intersection between existing arterial road and acces road to clay deposit become a busy junction and vehicle queue might be developed. Instalation of traffic signal is recommended to minimize delay and queue length.

The gate to the properties (clay, limestone, and plant site) will be designed in accordance with traffic load resulting from project activities.

C. Road Widening

Based on observation, the road width within the study area is relatively narrow to support the heavy vehicle movements. In order to provide better performance for traffic, road widening should be undertaken. For arterial road with quite high percentage of heavy vehicle minimum road width of 6.5 meters are recommended.

D. Heavy Vehicle and Trucks

- The transport and movement of equipment (trucks) should be limited to working hours only.
- The use of flagmen should be employed to regulate trucks entering and exiting the access roads to the highway or at the junction (if necessary).

6 CONCLUSION

1). The existing traffic flows on the studied road network are still far below road capacity. It can be seen that the value of volume capacity ratio mostly are below 0.5. Based on observation, there are no significant generated traffic flow occured on the roads in the study area, although the road width is narrow. The road widths are between 4 to 5 meters. For arterial road with quite high percentage of heavy vehicle minimum road width of 6.5 meters are recommended.

2). Traffic performance during construction phase are still in a good condition, As heavy vehicle with high axle load move along an existing road, road pavement will failure. Heavy vehicle has high axle load, which can be damaged road pavement. To minimize the impact of heavy vehicle to road pavement, it is proposed to overlay an existing road in the studied road network which is used to mobilize heavy vehicle from Dili.

3). Intersection between existing arterial road and acces road to clay deposit (Intersection A) become a busy junction and vehicle queue might be developed. Installation of traffic signal is recommended to minimize delay and queue length. Traffic signal installation causes no significant impact on the major roadway in the country.

4). During operation phase, all alternative routes are in a good traffic performance. Most road link experience low volume capacity ratio and average mean speed higher than 20 kmph. Nevertheless, the road width is relatively narrow, to provide better performance for traffic, road widening should be undertaken.

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7 REFFERENCE

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